PROPOSED
TOTAL MAXIMUM DAILY LOAD (TMDL)

for

E. Coli

in the

Watauga River Watershed (HUC 06010103)

Carter, Johnson, Sullivan, Unicoi, and Washington Counties,

Tennessee

FINAL

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LIST OF ABBREVIATIONS

ADB	Assessment Database
AFO	Animal Feeding Operation
BMP	Best Management Practices
BST	Bacteria Source Tracking
CAFO	Concentrated Animal Feeding Operation
CFR	Code of Federal Regulations
CFS	Cubic Feet per Second
CFU	Colony Forming Units
DEM	Digital Elevation Model
DWPC	Division of Water Pollution Control
E. coli	Escherichia coli
EPA	Environmental Protection Agency
GIS	Geographic Information System
HSPF	Hydrological Simulation Program - Fortran
HUC	Hydrologic Unit Code
LA	Load Allocation
LDC	Load Duration Curve
LSPC	Loading Simulation Program in C^{++}
MGD	Million Gallons per Day
MOS	Margin of Safety
MRLC	Multi-Resolution Land Characteristic
MS4	Municipal Separate Storm Sewer System
MST	Microbial Source Tracking
NHD	National Hydrography Dataset
NMP	Nutrient Management Plan
NPS	Nonpoint Source
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
PCR	Polymerase Chain Reaction
PDFE	Percent of Days Flow Exceeded
PFGE	Pulsed Field Gel Electrophoresis
Rf3	Reach File v.3
RM	River Mile
SSO	Sanitary Sewer Overflow
STP	Sewage Treatment Plant
SWMP	Storm Water Management Program
TDA	Tennessee Department of Agriculture
TDEC	Tennessee Department of Environment & Conservation
TDOT	Tennessee Department of Transportation
TMDL	Total Maximum Daily Load
TWRA	Tennessee Wildlife Resources Agency
USGS	United States Geological Survey
UCF	Unit Conversion Factor
WCS	Watershed Characterization System
WLA	Waste Load Allocation
WWTF	Wastewater Treatment Facility

SUMMARY SHEET

Total Maximum Daily Load for E. coli in Watauga Watershed (HUC 06010103)

Impaired Waterbody Information

State: Tennessee
Counties: Carter, Johnson, and Washington
Watershed: Watauga (HUC 06010103)
Constituents of Concern: E. coli

Impaired Waterbodies Addressed in This Document:

Waterbody ID	Waterbody	Miles Impaired
TN06010103006 – 1000	BOONES CREEK	19.31
TN06010103008 – 0200	CAMPBELL BRANCH	3.0
TN06010103020T – 0200	SINK BRANCH	2.0
TN06010103034 – 0300	TOWN CREEK	3.0
TN06010103034 – 2000	ROAN CREEK	6.0
TN06010103037 – 0400	CAMPBELL CREEK	10.8
TN06010103046 – 1000	SINKING CREEK	10.0
TN06010103635 – 0100	CASH HOLLOW CREEK	3.48
TN06010103635 – 1000	KNOB CREEK	12.3

Designated Uses:

The designated use classifications for waterbodies in the Watauga Watershed include fish and aquatic life, irrigation, livestock watering & wildlife, and recreation. Portions of Roan Creek are also designated as trout streams or naturally reproducing trout streams

Water Quality Targets:

Derived from *State of Tennessee Water Quality Standards, Chapter 1200-4-3, General Water Quality Criteria, January, 2004* for recreation use classification (most stringent):

> The concentration of the E. coli group shall not exceed 126 colony forming units per 100 mL, as a geometric mean based on a minimum of 5 samples collected from a given sampling site over a period of not more than 30 consecutive days with individual samples being collected at intervals of not less than 12 hours. For the purposes of determining the geometric mean, individual samples having an E. coli concentration of less than 1 per 100 mL shall be considered as having a concentration of 1 per 100 mL. In addition, the concentration of the E. coli group in any individual sample taken from a lake, reservoir, State Scenic River, or Tier II or III stream (1200-4-3-.06) shall

not exceed 487 colony forming units per 100 mL. The concentration of the E. coli group in any individual sample taken from any other waterbody shall not exceed 941 colony forming units per 100 mL.

TMDL Scope:

Waterbodies identified on the Final 2004 303(d) list as impaired due to E. coli. TMDLs were developed for impaired waterbodies on a HUC-12 subwatershed or waterbody drainage area basis. For Sinking Creek, Cash Hollow Creek, and Roan Creek (including Town Creek and Forge Creek), the TMDL analysis was revised due to the availability of new data. This revised TMDL supersedes the Fecal Coliform TMDLs approved by EPA in 2000 and 2001.

Analysis of monitoring data for Town Creek suggests that improvement in water quality has occurred since the previous TMDL was approved in 2001. At this time, delisting is suggested. No load reduction was required for Campbell Creek due to insufficient monitoring data. Additional monitoring is recommended to allow for either development of a TMDL or delisting.

Analysis/Methodology:

The TMDLs for impaired waterbodies in the Watauga Watershed were developed using a load duration curve methodology to assure compliance with the E. Coli 126 CFU/100 mL geometric mean and the 487 CFU/100 mL maximum water quality criteria for Tier II waterbodies and 941 CFU/100 mL maximum water quality criteria for non-Tier II waterbodies. A duration curve is a cumulative frequency graph that represents the percentage of time during which the value of a given parameter is equaled or exceeded. Load duration curves are developed from flow duration curves and can illustrate existing water quality conditions (as represented by loads calculated from monitoring data), how these conditions compare to desired targets, and the region of the waterbody flow regime represented by these existing loads. Load duration curves were used to determine the load reductions required to meet desired maximum concentrations for E. coli. When sufficient data were available, load reductions were also determined based on geometric mean criteria.

Critical Conditions:

Water quality data collected over a period of 10 years for load duration curve analysis were used to assess the water quality standards representing a range of hydrologic and meteorological conditions.

Seasonal Variation:

The 10-year period used for LSPC model simulation period for development of load duration curve analysis included all seasons and a full range of flow and meteorological conditions.

Margin of Safety (MOS):

Explicit MOS = 10% of the E. coli water quality criteria for each impaired subwatershed or drainage area.

Summary of TMDLs, WLAs, & LAs for Impaired Waterbodies

HUC-12 Subwatershed (06010103__) or Drainage Area	Impaired Waterbody Name	Impaired Waterbody ID	TMDL	WLAs				LAs	
				WWTFs [a,b]		CAFOs	MS4s [c]	Precipitation Induced Nonpoint Sources	Other Direct Sources [d]
				Monthly Avg.	Daily Max.				
			[% Red.]	[CFU/day]	[CFU/day]	[CFU/day]	[% Red.]	[% Red.]	[CFU/day]
0102	Town Creek	TN06010103034 – 0300	0	5.723×10^{9}	4.274×10^{10}	NA	NA	0	0
DA	Roan Creek	TN06010103034 – 2000	42.3	5.723×10^{9}	4.274×10^{10}	0	NA	48.1	0
DA	Campbell Creek	TN06010103037 – 0400	0	NA	NA	NA	NA	0	0
DA	Sink Branch	TN06010103020T – 0200	>61.1	NA	NA	NA	NA	>65.0	0
DA	Campbell Branch	TN06010103008 – 0200	>61.1	7.631×10^{7}	5.699×10^{8}	NA	>65.0	>65.0	0
0504	Sinking Creek	TN06010103046 – 1000	>68.6	NA	NA	NA	>71.8	>71.8	0
0505	Cash Hollow Creek	TN06010103035 - 0100	67.9	NA	NA	NA	71.2	71.2	0
	Knob Creek	TN06010103035 – 1000							
0508	Boones Creek	TN06010103006 – 1000	>59.6	NA	NA	NA	>63.7	>63.7	0

Notes: NA = Not Applicable.

a. Future WWTFs must meet instream water quality standards at the point of discharge as specified in their NPDES permit.

b. The WLAs listed apply to NPDES permitted discharges from WWTFs only. Pathogen loading due to collection system failure is considered to be unpermitted point source loading from the municipal WWTF. With respect to pathogen loading from leaking collection systems, a WLA of zero is assigned. It is recognized, however, that a WLA of 0 CFU/day may not be practical. For these unpermitted sources, the WLA is interpreted to mean a reduction in pathogen loading to the maximum extent practicable, consistent with the requirement that these sources not contribute to a violation of the water quality standard for E. coli.

c. Applies to any MS4 discharge loading in the subwatershed.

d. The objective for all “other direct sources” is a load allocation of zero. It is recognized, however, that for leaking septic systems a LA of 0 CFU/day may not be practical. For these sources, the LA is interpreted to mean a reduction in pathogen loading to the maximum extent practicable, consistent with the requirement that these sources not contribute to a violation of the water quality standard for E. coli.

PROPOSED E. COLI TOTAL MAXIMUM DAILY LOAD (TMDL) WATAUGA WATERSHED (HUC 06010103)

1.0 INTRODUCTION

Section 303(d) of the Clean Water Act requires each state to list those waters within its boundaries for which technology based effluent limitations are not stringent enough to protect any water quality standard applicable to such waters. Listed waters are prioritized with respect to designated use classifications and the severity of pollution. In accordance with this prioritization, states are required to develop Total Maximum Daily Loads (TMDLs) for those waterbodies that are not attaining water quality standards. State water quality standards consist of designated uses for individual waterbodies, appropriate numeric and narrative water quality criteria protective of the designated uses, and an antidegradation statement. The TMDL process establishes the maximum allowable loadings of pollutants for a waterbody that will allow the waterbody to maintain water quality standards. The TMDL may then be used to develop controls for reducing pollution from both point and nonpoint sources in order to restore and maintain the quality of water resources (USEPA, 1991).

2.0 SCOPE OF DOCUMENT

This document presents details of TMDL development for waterbodies in the Watauga Watershed, identified on the Final 2004 303(d) list as not supporting designated uses due to E. coli. Portions of the Watauga Watershed lie in both Tennessee and North Carolina. This document addresses only impaired waterbodies in Tennessee. TMDL analyses were performed primarily on a 12-digit hydrologic unit area (HUC-12) basis. In some cases, where appropriate, TMDLs were developed for an impaired waterbody drainage area only. For Sinking Creek, Cash Hollow Creek, and Roan Creek, the TMDL analysis was revised due to the availability of new data. This revised TMDL supersedes the Fecal Coliform TMDLs approved by EPA in 2000 and 2001.

Analysis of monitoring data for Town Creek suggests that improvement in water quality has occurred since the previous TMDL was approved in 2001. At this time, delisting is suggested. No load reduction was required for Campbell Creek due to insufficient monitoring data. Additional monitoring is recommended to allow for either development of a TMDL or delisting.

3.0 WATERSHED DESCRIPTION

The Watauga Watershed (HUC 06010103) is located in Eastern Tennessee (Figure 1), primarily in Carter and Johnson Counties. The Watauga Watershed lies within two Level III ecoregions (Blue Ridge Mountains, Ridge and Valley) and contains five Level IV ecoregions as shown in Figure 2 (USEPA, 1997):

- **Southern Igneous Ridges and Mountains (66d)** occur in Tennessee's northeastern Blue Ridge near the North Carolina border, primarily on Precambrian-age igneous and high-grade metamorphic rocks. The typical crystalline rock types include granite, gneiss, schist, and metavolcanics, covered by well-drained, acidic brown loamy soils. Elevations of this rough, dissected region range from 2000-6200 feet, with Roan Mountain reaching 6286 feet. Although there are a few small areas of pasture and apple orchards, the region is mostly forested; Appalachian oak and northern hardwood forests predominate.

- **The Southern Sedimentary Ridges (66e)** in Tennessee include some of the westernmost foothill areas of the Blue Ridges Mountains ecoregion, such as the Bean, Starr, Chilhowee, English, Stone, Bald, and Iron Mountain areas. Slopes are steep, and elevations are generally 1000-4500 feet. The rocks are primarily Cambrian-age sedimentary (shale, sandstone, siltstone, quartzite, conglomerate), although some lower stream reachs occur on limestone. Soils are predominantly friable loams and fine sandy loams with variable amounts of sandstone rock fragments, and support mostly mixed oak and oak-pine forests.

- **Limestone Valleys and Coves (66f)** are small but distinct lowland areas of the Blue Ridge, with elevations mostly between 1500 and 2500 feet. About 450 million years ago, older Blue Ridge rocks to the east were forced up and over younger rocks to the west. In places, the Precambrian rocks have eroded through to Cambrian or Ordovician-age limestones, as seen especially in isolated, deep cove areas that are surrounded by steep mountains. The main areas of limestone include the Mountain City lowland area and Shady Valley in the north; and Wear Cove, Tuckaleechee Cove, and Cades Cove of the Great Smoky Mountains in the south. Hay and pasture, with some tobacco patches on small farms, are typical land uses.

- **The Southern Limestone/Dolomite Valleys and Low Rolling Hills (67f)** form a heterogeneous region composed predominantly of limestone and cherty dolomite. Landforms are mostly low rolling ridges and valleys, and the solids vary in their productivity. Landcover includes intensive agriculture, urban and industrial, or areas of thick forest. White oak forests, bottomland oak forests, and sycamore-ash-elm riparian forests are the common forest types, and grassland barrens intermixed with cedar-pine glades also occur here.

- **The Southern Shale Valleys (67g)** consist of lowlands, rolling valleys, and slopes and hilly areas that are dominated by shale materials. The northern areas are associated with Ordovician-age calcareous shale, and the well-drained soils are often slightly acid to neutral. In the south, the shale valleys are associated with Cambrian-age shales that contain some narrow bands of limestone, but the soils tend to be strongly acid. Small farms and rural residences subdivide the land. The steeper slopes are used for pasture or have reverted to brush and forested land, while small fields of hay, corn , tobacco, and garden crops are grown on the foot slopes and bottomland.

The Watauga Watershed, located in Carter, Johnson, Sullivan, Unicoi, and Washington Counties, Tennessee, has a drainage area of approximately 668 square miles (mi^2) in Tennessee. The entire watershed drains approximately 816 mi^2. Watershed land use distribution is based on the Multi-Resolution Land Characteristic (MRLC) databases derived from Landsat Thematic Mapper digital images from the period 1990-1993. Although changes in the land use of the Watauga Watershed have occurred since 1993 as a result of development, this is the most current land use data available. Land use for the Watauga Watershed is summarized in Table 1 and shown in Figure 3. Predominant land use in the Watauga Watershed is forest (79.8%) followed by pasture (9.8%). Urban areas represent approximately 5% of the total drainage area of the watershed. Details of land use distribution of impaired subwatersheds in the Watauga Watershed are presented in Appendix A.

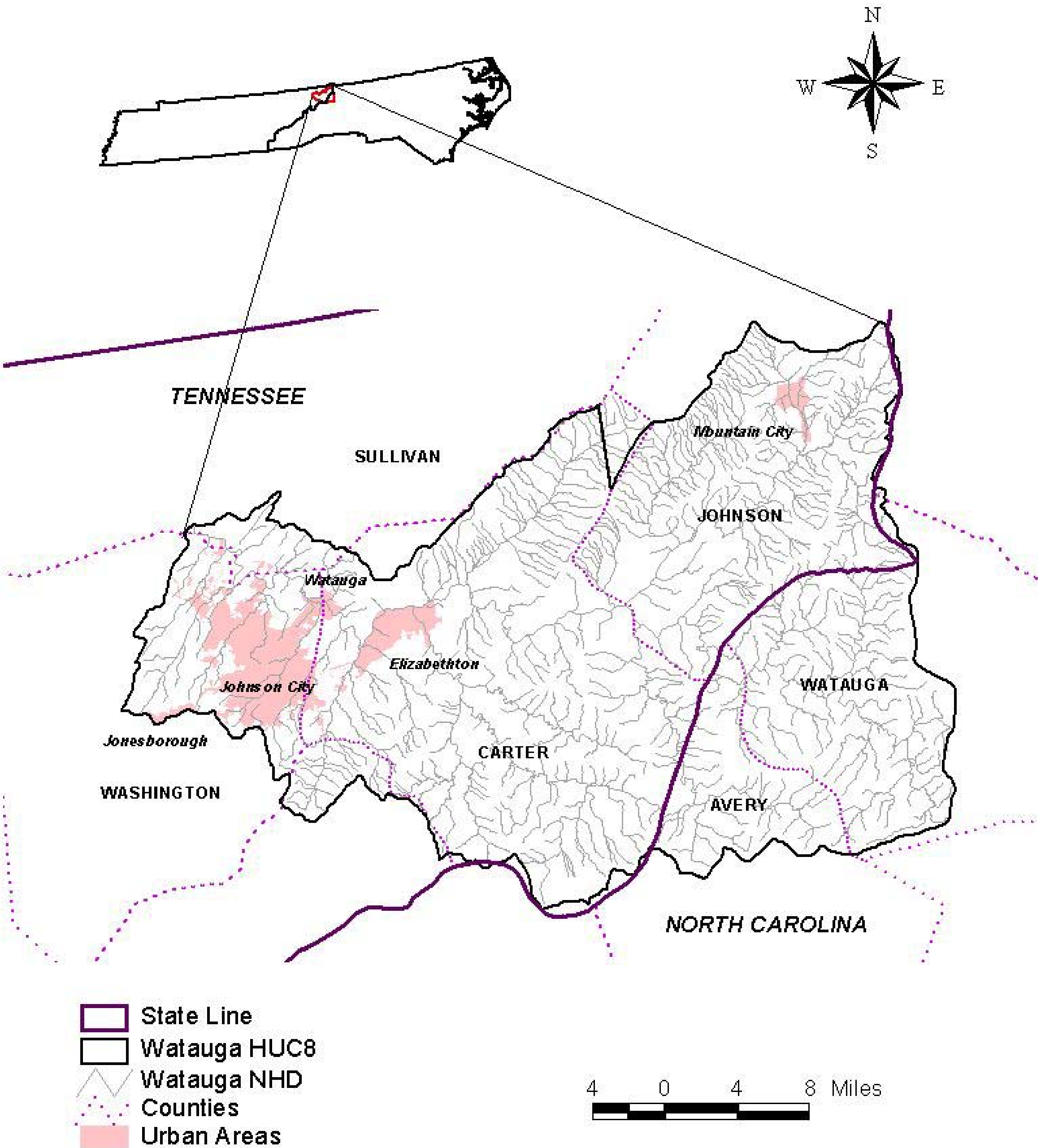

Figure 1. Location of the Watauga Watershed.

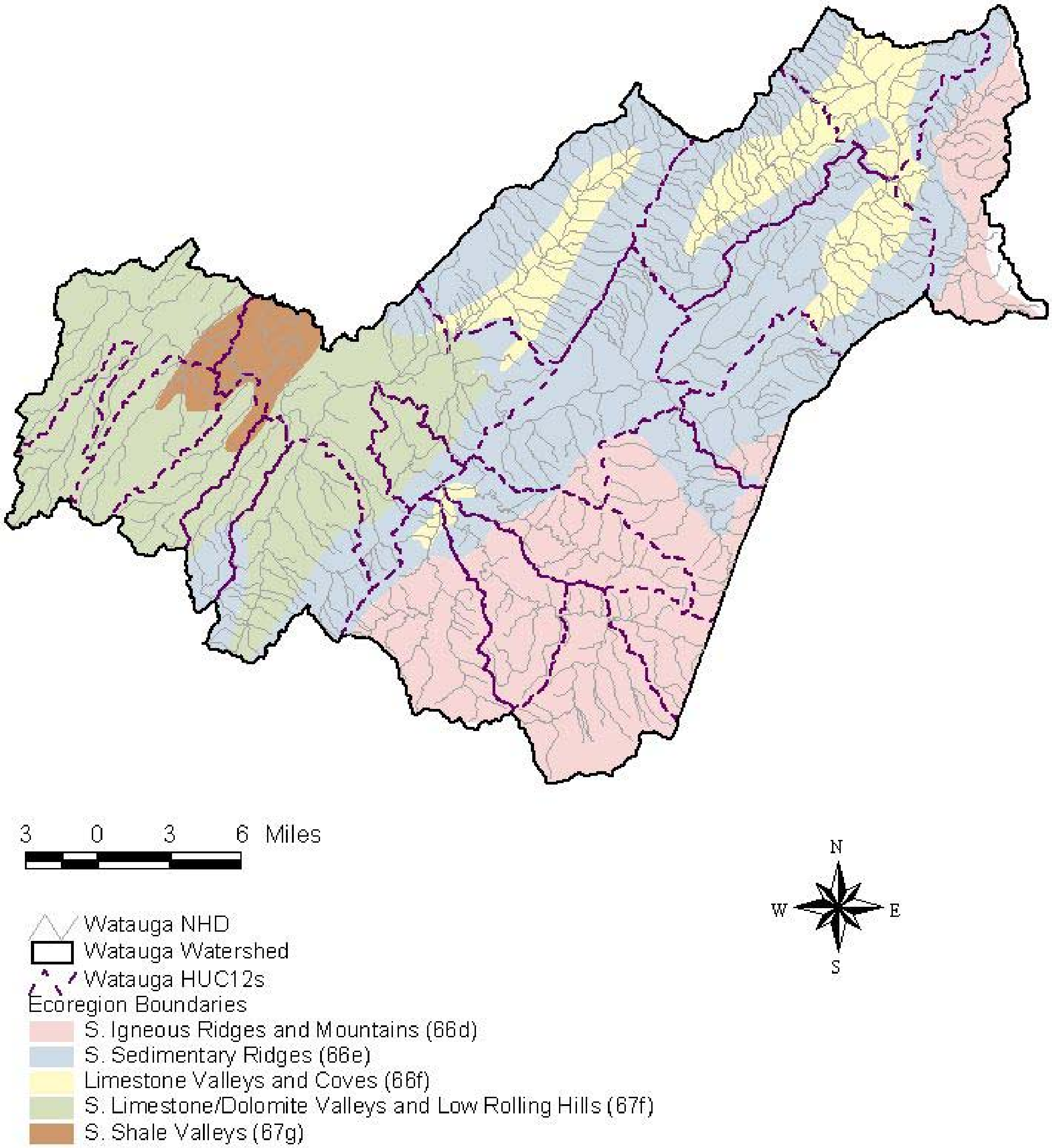

Figure 2. Level IV Ecoregions in the Watauga Watershed.

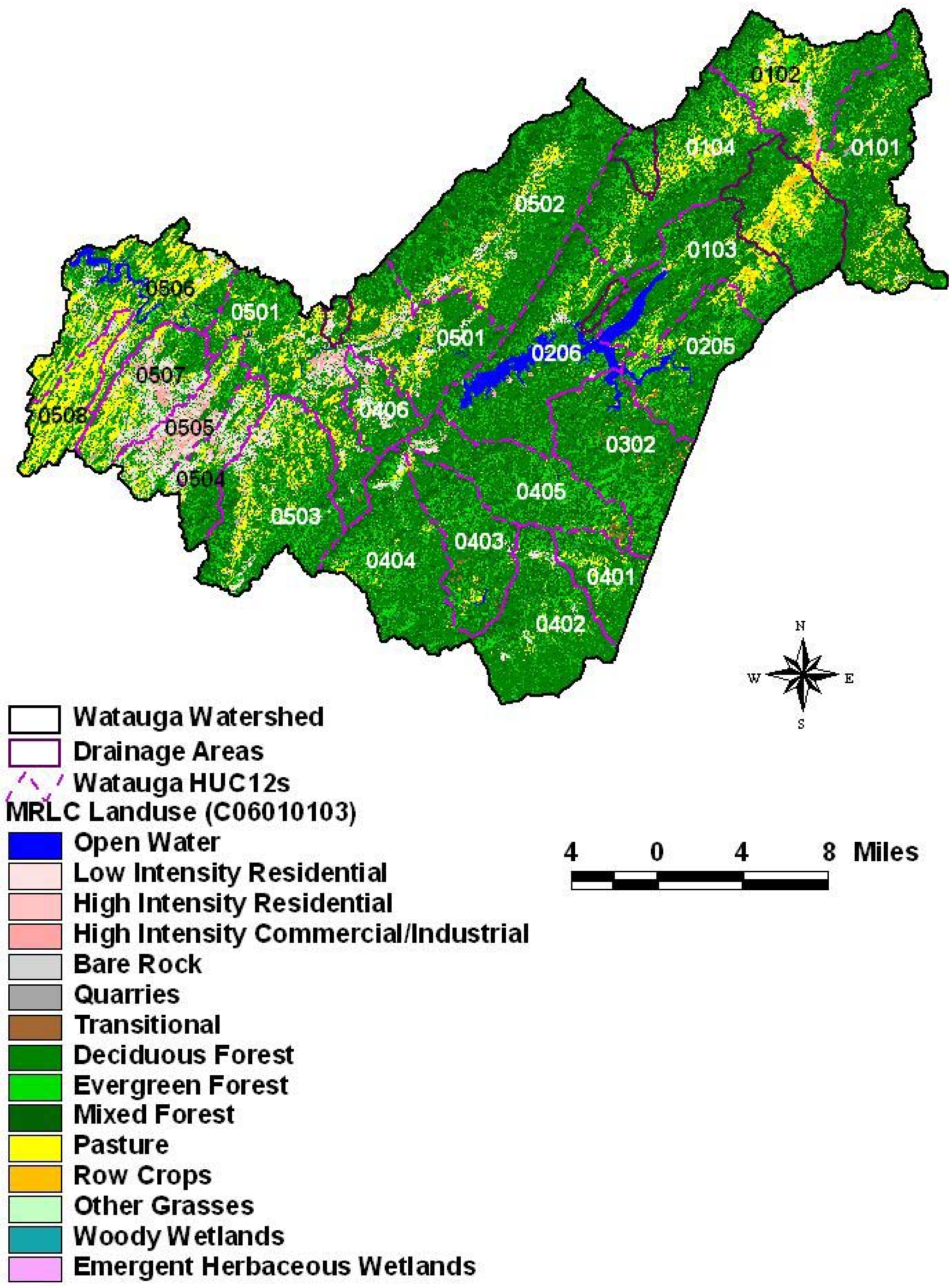

Figure 3. Land Use Characteristics of the Watauga Watershed.

Table 1. MRLC Land Use Distribution – Watauga Watershed

Land Use	Area	
	[acres]	[%]
Bare Rock/Sand/Clay	607	0.1
Deciduous Forest	183,412	42.9
Emergent Herbaceous Wetlands	136	0.0
Evergreen Forest	63,278	14.8
High Intensity Commercial/Industrial/ Transportation	4,910	1.1
High Intensity Residential	2,089	0.5
Low Intensity Residential	15,272	3.6
Mixed Forest	94,457	22.1
Open Water	7,523	1.8
Other Grasses (Urban/recreational)	2,848	0.7
Pasture/Hay	42,606	10.0
Quarries/Strip Mines/ Gravel Pits	155	0.0
Row Crops	8,447	2.0
Transitional	1,140	0.3
Woody Wetlands	489	0.1
Total	**427,371**	**100.0**

4.0 PROBLEM DEFINITION

The State of Tennessee's final 2004 303(d) list (TDEC, 2005) was approved by the U.S. Environmental Protection Agency (EPA), Region IV in August of 2005. This list identified portions of nine waterbodies in the Watauga Watershed as not supporting designated use classifications due, in part, to E. coli (see Table 2 & Figure 4). The designated use classifications for these waterbodies include fish and aquatic life, irrigation, livestock watering & wildlife, and recreation. Portions of Roan Creek are also designated as trout streams or naturally reproducing trout streams.

When used in the context of waterbody assessments, the term pathogens is defined as disease-causing organisms such as bacteria or viruses that can pose an immediate and serious health threat if ingested or introduced into the body. The primary sources for pathogens are untreated or inadequately treated human or animal fecal matter. The E. coli and fecal coliform groups are indicators of the presence of pathogens in a stream.

5.0 WATER QUALITY CRITERIA & TMDL TARGET

As previously stated, the designated use classifications for the Watauga waterbodies include fish & aquatic life, recreation, irrigation, and livestock watering & wildlife. Of the use classifications with numeric criteria for pathogens, the recreation use classification is the most stringent and will be used to establish target levels for TMDL development. The coliform water quality criteria, for protection of the recreation use classification, is established by *State of Tennessee Water Quality Standards, Chapter 1200-4-3, General Water Quality Criteria, January 2004* (TDEC, 2004). Section 1200-4-3-.03 (4) (f) states:

> The concentration of the E. coli group shall not exceed 126 colony forming units per 100 mL, as a geometric mean based on a minimum of 5 samples collected from a given sampling site over a period of not more than 30 consecutive days with individual samples being collected at intervals of not less than 12 hours. For the purposes of determining the geometric mean, individual samples having an E. coli concentration of less than 1 per 100 mL shall be considered as having a concentration of 1 per 100 mL.
>
> Additionally, the concentration of the E. coli group in any individual sample taken from a lake, reservoir, State Scenic River, or Tier II or III stream (1200-4-3-.06) shall not exceed 487 colony forming units per 100 mL. The concentration of the E. coli group in any individual sample taken from any other waterbody shall not exceed 941 colony forming units per 100 mL.

Portions of Campbell Creek and Sinking Creek within the Cherokee National Forest have been classified as Tier II streams. Portions of Roan Creek (from Watauga River to Mile 16.7 and Mile 17.7 to origin) also have been classified as Tier II streams. As of February 2, 2006, none of the other E. coli impaired waterbodies in the Watauga Watershed have been classified as either Tier II or Tier III streams.

The geometric mean standard for the E. coli group of 126 colony forming units per 100 ml (CFU/100 ml) and the sample maximum of 487 CFU/100 ml have been selected as the appropriate numerical targets for TMDL development for impaired waterbodies classified as Tier II streams. The geometric mean standard for the E. coli group of 126 colony forming units per 100 ml (CFU/100 ml) and the sample maximum of 941 CFU/100 ml have been selected as the appropriate numerical targets for TMDL development for the other impaired waterbodies.

Table 2 Final 2004 303(d) List for E. coli Impaired Waterbodies – Watauga Watershed

Waterbody ID	Impacted Waterbody	Miles/Acres Impaired	Cause (Pollutant)	Pollutant Source
TN06010103006 – 1000	BOONES CREEK	19.31	Nitrates Siltation Alteration in stream-side or littoral vegetative cover Escherichia coli	Discharges from MS4 Area Pasture Grazing Land Development
TN06010103008 – 0200	CAMPBELL BRANCH	3.0	Nitrates Siltation Alteration in stream-side or littoral vegetative cover Escherichia coli	Discharges from MS4 Area
TN06010103020T – 0200	SINK BRANCH	2.0	Alterations in stream-side or littoral vegetative cover Nitrates Escherichia coli	Pasture Grazing
TN06010103034 – 0300	TOWN CREEK	3.0	Solids Escherichia coli	Municipal Point Source Discharge
TN06010103034 – 2000	ROAN CREEK	6.0	Nitrates Siltation Escherichia coli	Municipal Point Source Discharge Pasture Grazing
TN06010103037 – 0400	CAMPBELL CREEK	10.8	Escherichia coli	Septic Tanks Pasture Grazing
TN06010103046 – 1000	SINKING CREEK	10.0	Escherichia coli	Discharges from MS4 Area Pasture Grazing
TN06010103635 – 0100	CASH HOLLOW CREEK	3.48	Alteration in stream-side or littoral vegetative cover Escherichia coli	Discharges from MS4 Area
TN06010103635 – 1000	KNOB CREEK	12.13	Alteration in stream-side or littoral vegetative cover Nitrates Siltation Escherichia coli	Discharges from MS4 Area Pasture Grazing

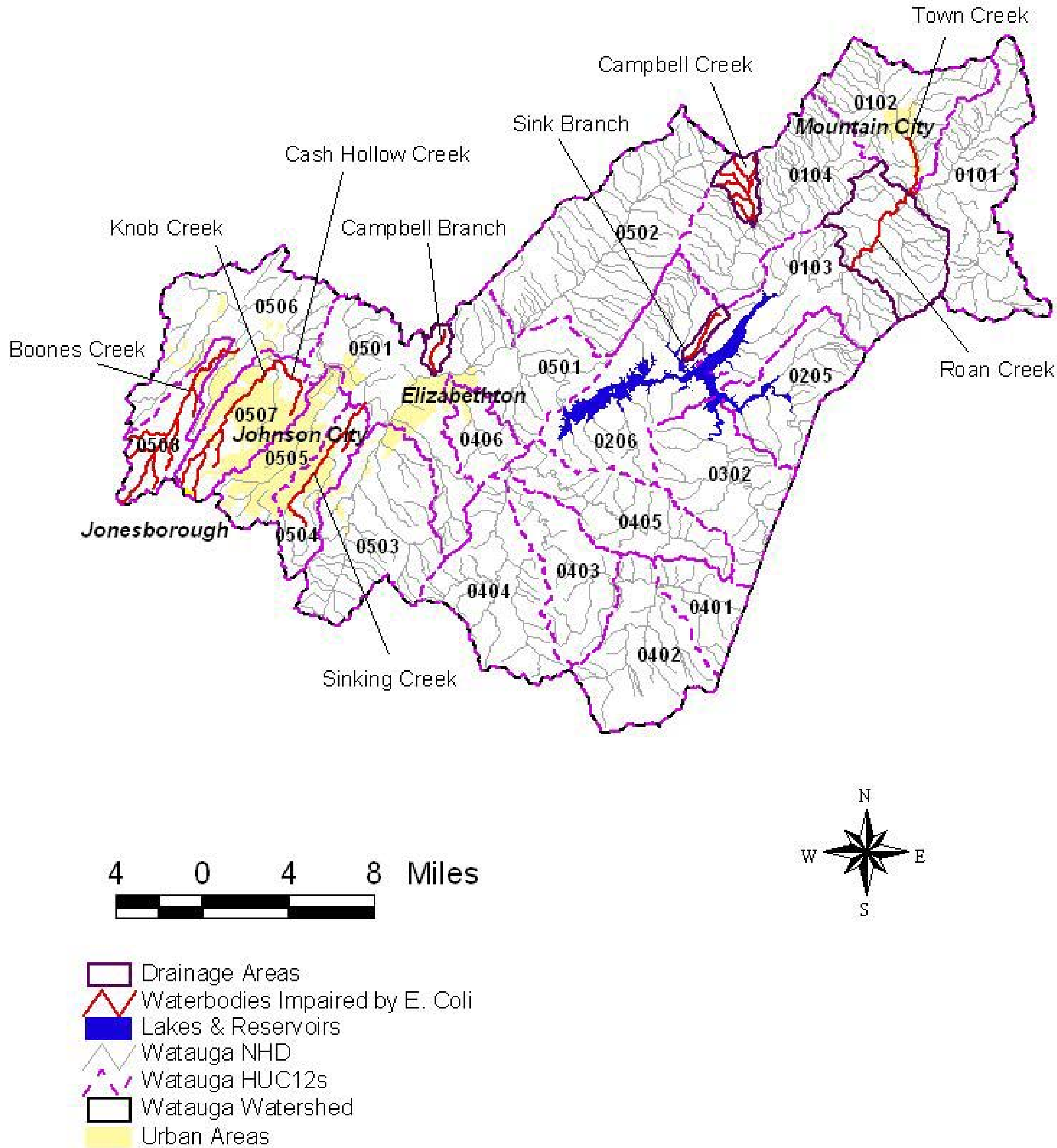

Figure 4. Waterbodies Impaired by E. Coli (as Documented on the Final 2004 303(d) List).

6.0 WATER QUALITY ASSESSMENT AND DEVIATION FROM TARGET

There are several water quality monitoring stations that provide data for waterbodies identified as impaired for E. coli in the Watauga Watershed. Monitoring stations located on Tier II waterboides have been italicized:

- Boones Creek Subwatershed:
  - BOONE001.7WN – Boones Creek, at Pickens Bridge Rd.
  - BOONE003.7WN – Boones Creek, at Christian Church Rd.
  - BOONE007.6WN – Boones Creek, on Bugaboo Springs Rd. (Susong Springs area)
- Campbell Branch Subwatershed:
  - CAMPB000.3CT – Campbell Branch, Biltmore S/D
- Sink Branch Subwatershed:
  - SINK000.7JO – Sink Branch, at Sink Valley Rd.
- Roan Creek Subwatershed:
  - FORGE000.5JO – Forge Creek, d/s of quarry
  - *ROAN007.5JO – Roan Creek, at farmhouse destroyed by tornado*
  - *ROAN011.6JO – Roan Creek, at confluence with Mill Creek*
  - *ROAN016.4JO – Roan Creek, at Maymead Farm*
  - *ROAN017.9JO – Roan Creek, bridge at church, u/s of STP*
  - TOWN000.9JO – Town Creek, at Dotson Lane
  - TOWN1T0.3JO – Unnamed tributary to Town Creek, at Rainbow Rd.
- Campbell Creek Subwatershed:
  - *CAMPB000.4JO – Campbell Creek, on Campbell Rd., near Pandora*
- Sinking Creek Subwatershed:
  - *SINKI000.6CT – Sinking Creek, at new pump station*
  - *SINKI001.1CT – Sinking Creek, d/s church, at Bob Peoples bridge*
  - *SINKI002.9WN – Sinking Creek, old station at Orlando Dr.*
  - *SINKI004.5WN – Sinking Creek, intersection of Lafe Cox Dr. & Buffalo Rd.*
  - *SINKI005.5WN – Sinking Creek, at Hughes Farm*
- Knob Creek Subwatershed:
  - CHOLL000.3WN – Cash Hollow Creek, near Austin Springs Rd.
  - CHOLL000.5WN – Cash Hollow Creek, at Cash Hollow Rd. bridge
  - CHOLL001.5WN – Cash Hollow Creek, at Morning Star Creek

- Knob Creek Subwatershed (cont'd):
    - CHOLL002.7WN – Cash Hollow Creek, intersection of Lakeview Dr. & Cash Hollow Rd.
    - KNOB001.0WN – Knob Creek, at Austin Springs Rd.
    - KNOB003.7WN – Knob Creek, d/s SR 36
    - KNOB005.8WN – Knob Creek, Knob Creek Rd. (Indian Ridge)

The location of these monitoring stations is shown in Figure 5. Water quality monitoring results for these stations are tabulated in Appendix B. Examination of the data shows exceedances of the 487 CFU/100 mL (Tier II) and 941 CFU/100 mL (non-Tier II) maximum E. coli standard at many monitoring stations. Water quality monitoring results for those stations with 10% or more of samples exceeding water quality maximum criteria are summarized in Table 3.

There were not enough data to calculate the geometric mean at each monitoring station. Whenever a minimum of 5 samples was collected at a given monitoring station over a period of not more than 30 consecutive days, the geometric mean was calculated.

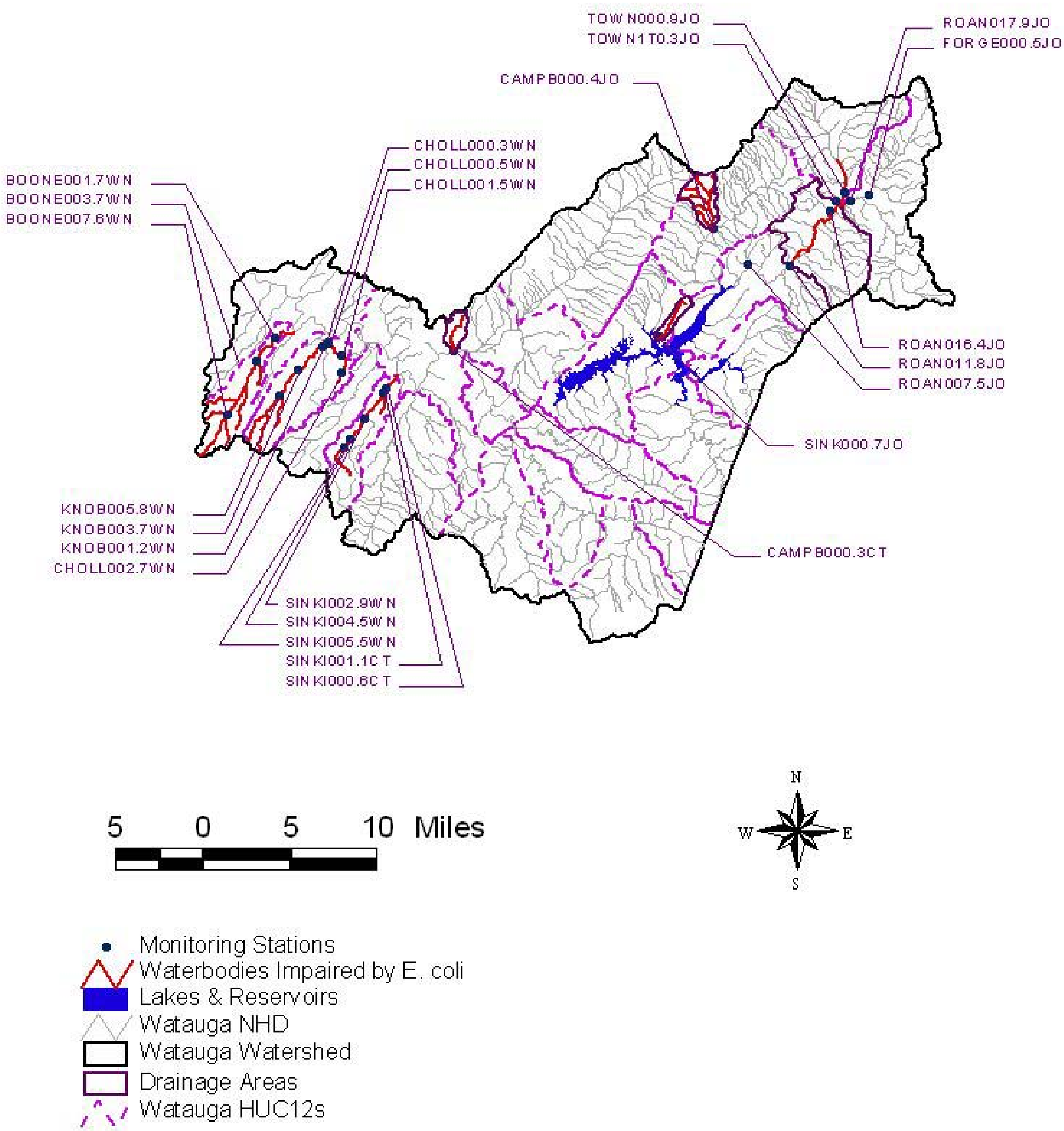

Figure 5. Water Quality Monitoring Stations in the Watauga Watershed

Table 3 Summary of TDEC Water Quality Monitoring Data

Monitoring Station	Date Range	E. Coli (Max WQ Target = 941 CFU/100 mL)**				
		Data Pts.	Min. [CFU/100 ml]	Avg. [CFU/100 ml]	Max. [CFU/100 ml]	No. Exceed. WQ Max. Target
BOONE001.7WN	2001 – 2002	3	488	1,132	>2,419	1
BOONE003.7WN	2001 – 2002	3	727	1,305	1,986	2
BOONE007.6WN	2001 – 2002	3	461	1,622	>2,419	2
CAMPB000.3CT	2001 – 2002	4	488	1,828	>2,419	3
CAMPB000.4JO	*2001 – 2002*	*4*	*3*	*181*	*548*	*1*
CHOLL000.3WN	1999 – 2000	11	114	619	>2,419	2
CHOLL001.5WN	1999 – 2000	12	20	363	1,300	2
KNOB001.0WH	2001 – 2002	3	93	694	1,553	1
KNOB003.7WN	2001 – 2002	3	613	1,253	>2,419	1
KNOB005.8WN	2001 – 2002	3	1,986	2,130	>2,419	3
ROAN016.4JO	*1998 – 2002*	*17*	*7*	*216*	*921*	*3*
ROAN017.9JO	*1998 – 2002*	*16*	*5*	*125*	*579*	*2*
SINK000.7JO	*2001 – 2002*	*3*	*921*	*1,920*	*>2,419*	*2*
SINKI000.6CT	*1999 – 2000*	*11*	*44*	*506*	*>2,419*	*3*
SINKI001.1CT	*1999 – 2000*	*12*	*37*	*430*	*>2,419*	*2*

** Maximum water quality target is 487 CFU/100 mL for Tier II waterbodies and 941 CFU/100 mL for other waterbodies. Tier II waterbodies are italicized.

7.0 SOURCE ASSESSMENT

An important part of TMDL analysis is the identification of individual sources, or source categories of pollutants in the watershed that affect pathogen loading and the amount of loading contributed by each of these sources.

Under the Clean Water Act, sources are classified as either point or nonpoint sources. Under 40 CFR §122.2, a point source is defined as a discernable, confined, and discrete conveyance from which pollutants are or may be discharged to surface waters. The National Pollutant Discharge Elimination System (NPDES) program regulates point source discharges. Point sources can be described by three broad categories: 1) NPDES regulated municipal and industrial wastewater treatment facilities (WWTFs); 2) NPDES regulated industrial and municipal storm water discharges; and 3) NPDES regulated Concentrated Animal Feeding Operations (CAFOs). A TMDL must provide Waste Load Allocations (WLAs) for all NPDES regulated point sources. Nonpoint sources are diffuse sources that cannot be identified as entering a waterbody through a discrete conveyance at a single location. For the purposes of this TMDL, all sources of pollutant loading not regulated by NPDES permits are considered nonpoint sources. The TMDL must provide a Load Allocation (LA) for these sources.

7.1 Point Sources

7.1.1 NPDES Regulated Municipal and Industrial Wastewater Treatment Facilities

Both treated and untreated sanitary wastewater contain coliform bacteria. There are 10 WWTFs in the Watauga Watershed that have NPDES permits authorizing the discharge of treated sanitary wastewater. Two of these facilities are located in impaired subwatersheds or drainage areas (see Table 4 & Figure 6). The permit limits for discharges from these WWTFs are in accordance with the coliform criteria specified in Tennessee Water Quality Standards for the protection of the recreation use classification.

Note: As stated in Section 5.0, the current coliform criteria are expressed in terms of E. coli concentration, whereas previous criteria were expressed in terms of fecal coliform and E. coli concentration. Due to differences in permit issuance dates, some permits still have fecal coliform limits instead of E. coli. As permits are reissued, limits for fecal coliform will be replaced by E. coli limits.

Table 4 NPDES Permitted WWTFs in Impaired Subwatersheds or Drainage Areas

NPDES Permit No.	Facility	Design Flow [MGD]	Receiving Stream
TN0023736	Keenburg Elementary School	0.016	Unnamed tributary to Campbell Branch at Mile 1.7
TN0024945	Mountain City STP	1.2	Town Creek at Mile 0.4 to Roan Creek at Mile 17.7

* Long term average flow is used for industrial facilities.

A summary of effluent monitoring data, submitted on Discharge Monitoring Reports (DMRs) for the period from April 2002 to October 2005, for facilities that are located in HUC-12 subwatersheds or drainage areas containing waterbodies impaired for pathogens is presented in Table 5. DMRs are not required for “package plants” such as those in operation at the Keenburg Elementary Schools. Monthly Operation Reports (MORs) are submitted to the local Environmental Field Office.

Table 5 Summary of DMRs for NPDES Permitted WWTFs in Impaired Subwatersheds or Drainage Areas

NPDES Permit No.	E. Coli (Permit Limit = 126 CFU/100 mL Avg.)					Fecal Coliform (Permit Limit = 200 CFU/100 mL Avg.)					Fecal Coliform (Permit Limit = 1000 CFU/100 mL Max.)					No. Bypass/ Overflow Events
	Data Pts.	Min. (CFU/100 mL)	Avg. (CFU/100 mL)	Max. (CFU/100 mL)	No. Exceed.	Data Pts.	Min. (CFU/100 mL)	Avg. (CFU/100 mL)	Max. (CFU/100 mL)	No. Exceed.	Data Pts.	Min. (CFU/100 mL)	Avg. (CFU/100 mL)	Max. (CFU/100 mL)	No. Exceed.	
TN0024945	43	1	45	459	4	43	1	13	157	0	43	2	491	6000	3	39

Due to differences in permit issuance dates, some permits still have fecal coliform limits instead of E. coli. As permits are reissued, limits for fecal coliform will be replaced by E. coli limits. Fecal coliform data are presented for informational purposes only.

According to a Compliance Evaluation Inspection conducted in May 2004, efforts to reduce inflow and infiltration must be continued at the Mountain City STP.

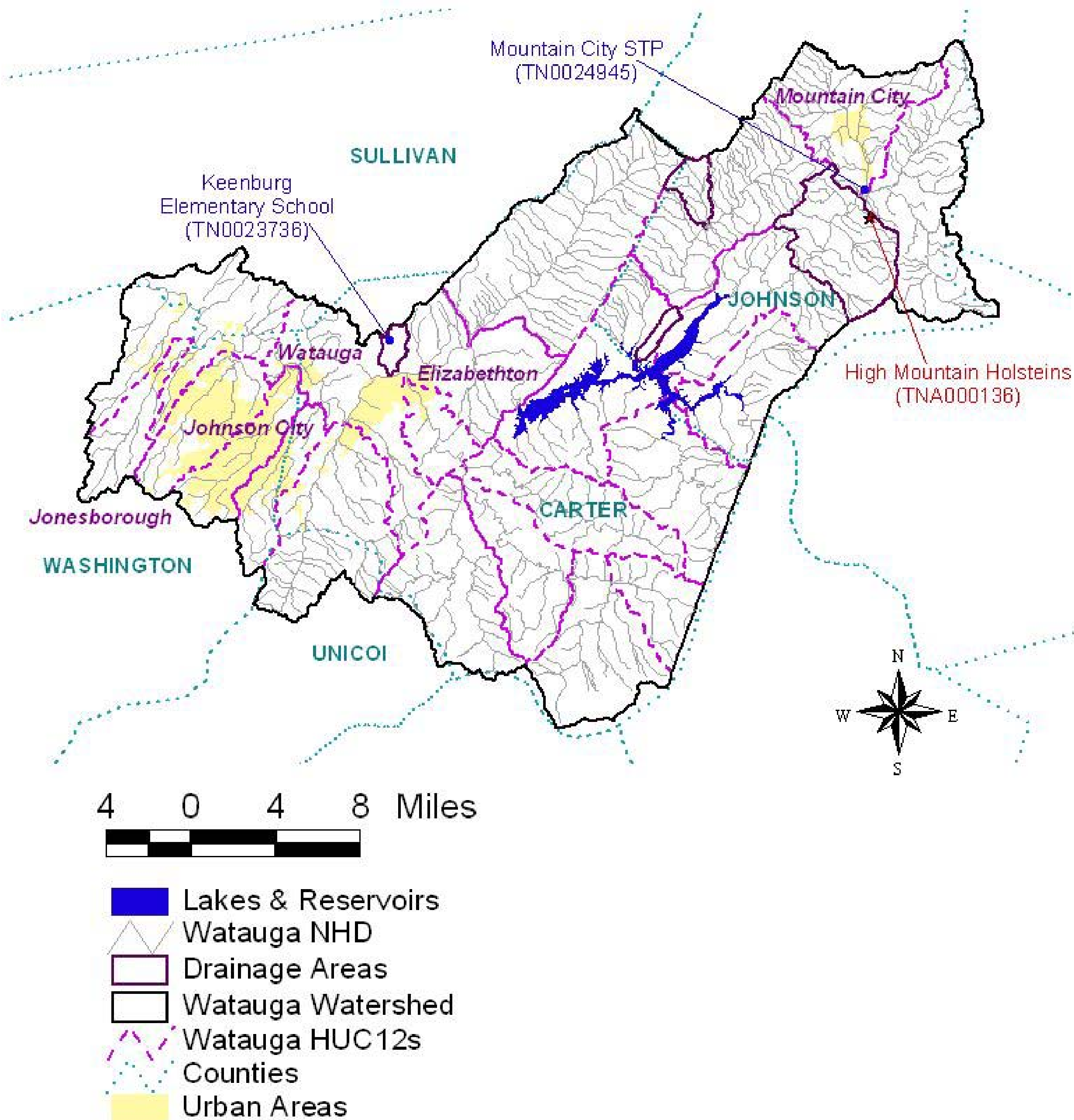

Figure 6. NPDES Regulated Point Sources in and near Impaired Subwatersheds and Drainage Areas of the Watauga Watershed.

7.1.2 NPDES Regulated Municipal Separate Storm Sewer Systems (MS4s)

Municipal Separate Storm Sewer Systems (MS4s) are considered to be point sources of E. coli. Discharges from MS4s occur in response to storm events through road drainage systems, curb and gutter systems, ditches, and storm drains. Large and medium MS4s serving populations greater than 100,000 people are required to obtain NPDES storm water permits. At present, there are no large and medium (Phase I) MS4s in the Watauga Watershed.

As of March 2003, small MS4s serving urbanized areas, or having the potential to exceed instream water quality standards, are required to obtain a permit under the *NPDES General Permit for Discharges from Small Municipal Separate Storm Sewer Systems* (TDEC, 2002). An urbanized area is defined as an entity with a residential population of at least 50,000 people and an overall population density of at least 1,000 people per square mile. Elizabethton, Johnson City, Jonesborough, Carter County, Sullivan County, and Washington County are covered under Phase II of the NPDES Storm Water Program. The Tennessee Department of Transportation (TDOT) is also being issued Phase II MS4 permits for State roads in urban areas. Information regarding storm water permitting in Tennessee may be obtained from the TDEC website at:

http://www.state.tn.us/environment/wpc/stormh2o/.

7.1.3 NPDES Concentrated Animal Feeding Operations (CAFOs)

Animal feeding operations (AFOs) are agricultural enterprises where animals are kept and raised in confined situations. AFOs congregate animals, feed, manure and urine, dead animals, and production operations on a small land area. Feed is brought to the animals rather than the animals grazing or otherwise seeking feed in pastures, fields, or on rangeland (USEPA, 2002a). Concentrated Animal Feeding Operations (CAFOs) are AFOs that meet certain criteria with respect to animal type, number of animals, and type of manure management system. CAFOs are considered to be potential point sources of pathogen loading and are required to obtain an NPDES permit. Most CAFOs in Tennessee obtain coverage under TNA000000, *Class II Concentrated Animal Feeding Operation General Permit*, while larger, Class I CAFOs are required to obtain an individual NPDES permit.

As of May 11, 2005, there is one Class II CAFO in the Watauga watershed with coverage under the general NPDES permit. High Mountain Holsteins, LLC, (TNA000138) is located in the Roan Creek watershed. There are no Class I CAFOs with individual permits located in the watershed.

7.2 Nonpoint Sources

Nonpoint sources of coliform bacteria are diffuse sources that cannot be identified as entering a waterbody through a discrete conveyance at a single location. These sources generally, but not always, involve accumulation of coliform bacteria on land surfaces and wash off as a result of storm events. Nonpoint sources of E. coli loading are primarily associated with agricultural and urban land uses. The majority of waterbodies identified on the Final 2004 303(d) list as impaired due to E. coli are attributed to nonpoint agricultural or urban sources.

7.2.1 Wildlife

Wildlife deposit coliform bacteria, with their feces, onto land surfaces where it can be transported during storm events to nearby streams. The overall deer density for Tennessee was estimated by the Tennessee Wildlife Resources Agency (TWRA) to be 23 animals per square mile.

7.2.2 Agricultural Animals

Agricultural activities can be a significant source of coliform bacteria loading to surface waters. The activities of greatest concern are typically those associated with livestock operations:

- Agricultural livestock grazing in pastures deposit manure containing coliform bacteria onto land surfaces. This material accumulates during periods of dry weather and is available for washoff and transport to surface waters during storm events. The number of animals in pasture and the time spent grazing are important factors in determining the loading contribution.
- Processed agricultural manure from confined feeding operations is often applied to land surfaces and can provide a significant source of coliform bacteria loading. Guidance for issues relating to manure application is available through the University of Tennessee Agricultural Extension Service and the Natural Resources Conservation Service (NRCS).
- Agricultural livestock and other unconfined animals often have direct access to waterbodies and can provide a concentrated source of coliform bacteria loading directly to a stream.

Data sources related to livestock operations include the 2002 Census of Agriculture, which was compiled for the Watauga Watershed utilizing the Watershed Characterization System (WCS). WCS is an Arcview geographic information system (GIS) based program developed by USEPA Region IV to facilitate watershed characterization and TMDL development. Livestock information provided in WCS is based on the ratio of watershed pasture area to county pasture area applied to the livestock population within the county. Livestock data for E. coli-impaired watersheds are summarized in Table 6. Populations were rounded to the nearest 25 cows, 50 poultry, and 5 hogs, sheep, and horses.

7.2.3 Failing Septic Systems

Some coliform loading in the Watauga Watershed can be attributed to failure of septic systems and illicit discharges of raw sewage. Estimates from 1997 county census data of people in the Watauga Watershed utilizing septic systems were compiled using the WCS and are summarized in Table 7. In middle and eastern Tennessee, it is estimated that there are approximately 2.37 people per household on septic systems, some of which can be reasonably assumed to be failing. As with livestock in streams, discharges of raw sewage provide a concentrated source of coliform bacteria directly to waterbodies.

7.2.4 Urban Development

Nonpoint source loading of coliform bacteria from urban land use areas is attributable to multiple sources. These include: stormwater runoff, illicit discharges of sanitary waste, runoff from improper disposal of waste materials, leaking septic systems, and domestic animals. Impervious surfaces in urban areas allow runoff to be conveyed to streams quickly, without interaction with soils and groundwater. All impaired subwatersheds in the Watauga Watershed have less than 4.0% urban land use. Land use for the Watauga impaired drainage areas is summarized in Figures 7 through 10 and tabulated in Appendix A.

Table 6 Livestock Distribution in the Watauga Watershed

HUC-12 Subwatershed (06010103__) or Drainage Area	Livestock Population (WCS)					
	Beef Cow	Milk Cow	Poultry	Hogs	Sheep	Horse
0102 (Town Creek)	425	25	50	10	5	10
Roan Creek DA	325	25	50	10	0	10
Campbell Creek DA	75	0	0	0	0	0
Sink Branch DA	25	0	0	0	0	0
Campbell Branch DA	25	0	0	0	0	0
0504 (Sinking Creek)	675	125	0	5	0	10
0505 (Cash Hollow and Knob Creeks)	1,575	300	50	10	15	35
0508 (Boones Creek)	1,000	200	0	5	25	60

Table 7 Population on Septic Systems in the Watauga Watershed

HUC-12 Subwatershed (06010103__) or Drainage Area	Population on Septic Systems
0102 (Town Creek)	1,376
Roan Creek DA	894
Campbell Creek DA	196
Sink Branch DA	55
Campbell Branch DA	238
0504 (Sinking Creek)	1,971
0505 (Cash Hollow and Knob Creeks)	2,955
0508 (Boones Creek)	3,617

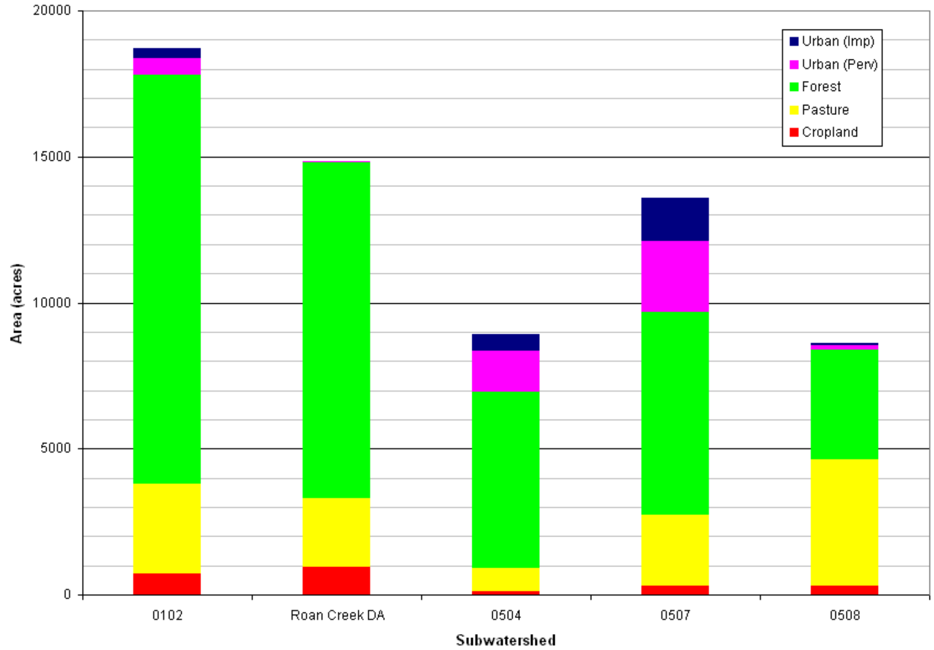

Figure 7. Land Use Area of Watauga Pathogen-Impaired Subwatersheds – Drainage Areas Greater Than 5,000 Acres

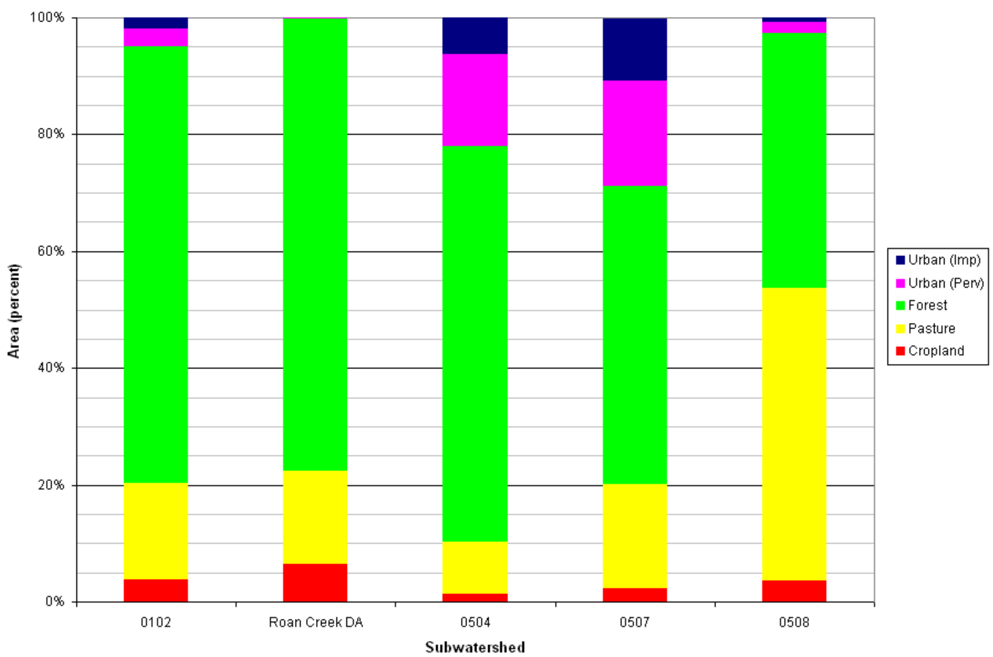

Figure 8. Land Use Percent of the Watauga Pathogen-Impaired Subwatersheds – Drainage Areas Greater Than 5,000 Acres

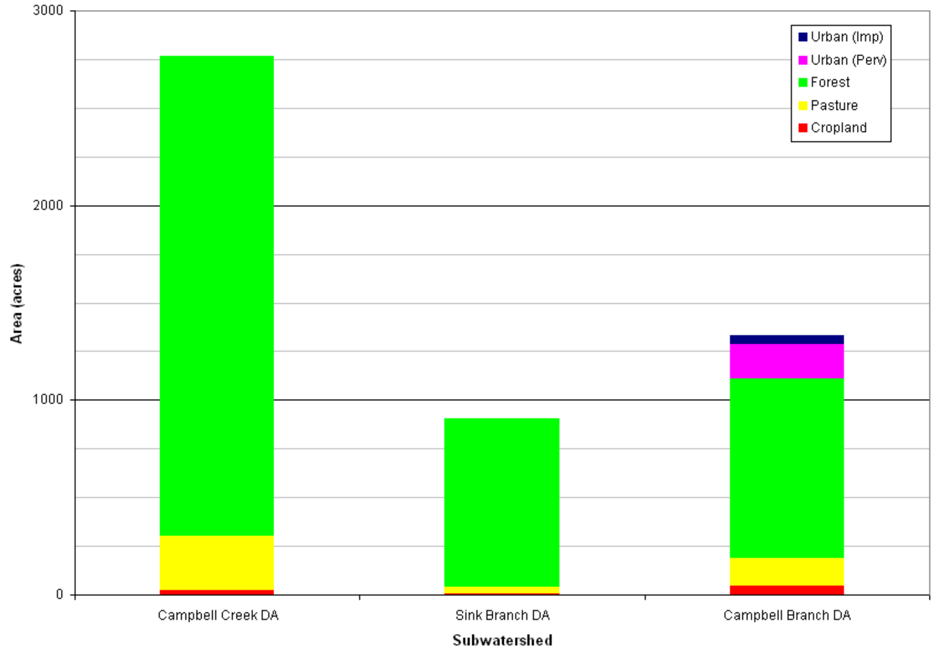

Figure 9. Land Use Area of Watauga Pathogen-Impaired Subwatersheds – Drainage Areas Less Than 5,000 Acres

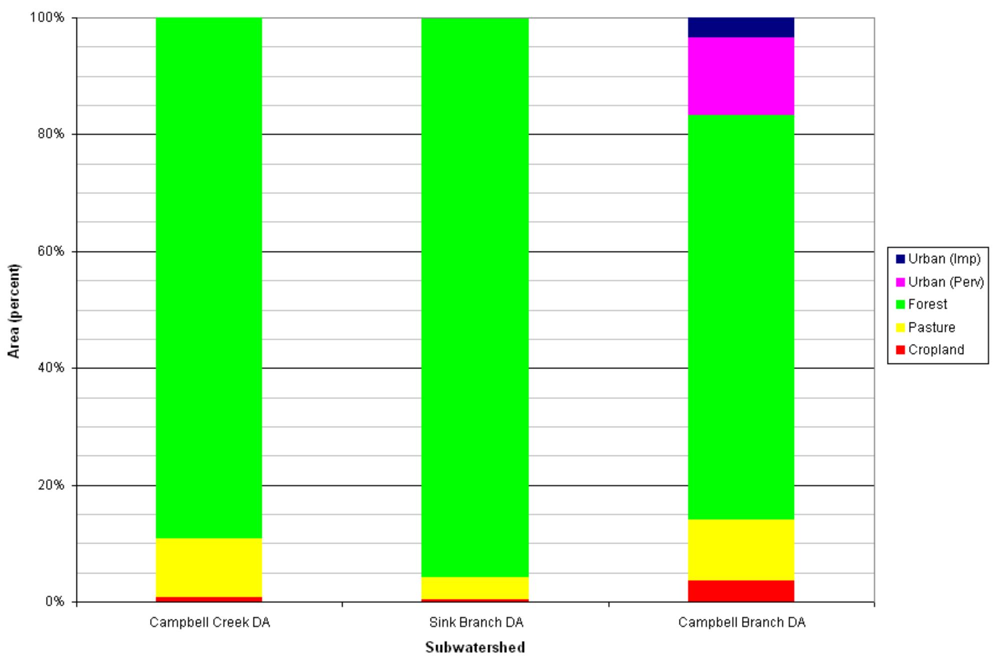

Figure 10. Land Use Percent of the Watauga Pathogen-Impaired Subwatersheds – Drainage Areas Less Than 5,000 Acres

8.0 DEVELOPMENT OF TOTAL MAXIMUM DAILY LOADS

The Total Maximum Daily Load (TMDL) process quantifies the amount of a pollutant that can be assimilated in a waterbody, identifies the sources of the pollutant, and recommends regulatory or other actions to be taken to achieve compliance with applicable water quality standards based on the relationship between pollution sources and in-stream water quality conditions. A TMDL can be expressed as the sum of all point source loads (Waste Load Allocations), non-point source loads (Load Allocations), and an appropriate margin of safety (MOS) that takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

$$\text{TMDL} = \Sigma\ \text{WLAs} + \Sigma\ \text{LAs} + \text{MOS}$$

The objective of a TMDL is to allocate loads among all of the known pollutant sources throughout a watershed so that appropriate control measures can be implemented and water quality standards achieved. 40 CFR §130.2 (i) states that TMDLs can be expressed in terms of mass per time, toxicity, or <u>other appropriate measure</u>.

This document describes TMDL, Waste Load Allocation (WLA), and Load Allocation (LA) development for waterbodies identified as impaired due to E. coli on the Final 2004 303(d) list.

8.1 Expression of TMDLs, WLAs, & LAs

In this document, TMDLs are expressed as the percent reduction in instream loading required to decrease existing E. coli concentrations to desired target levels. WLAs & LAs for precipitation-induced loading sources are also expressed as required percent reductions in E. coli loading. Allocations for loading that is independent of precipitation (WLAs for WWTFs and LAs for "other direct sources") are expressed as CFU/day.

8.2 Area Basis for TMDL Analysis

The primary area unit of analysis for TMDL development was the HUC-12 subwatershed containing one or more waterbodies assessed as impaired due to E. coli (as documented on the 2004 303(d) List). In some cases, however, TMDLs were developed for an impaired waterbody drainage area only. Determination of the appropriate area to use for analysis (see Table 8) was based on a careful consideration of a number of relevant factors, including: 1) location of impaired waterbodies in the HUC-12 subwatershed; 2) land use type and distribution; 3) water quality monitoring data; and 4) the assessment status of other waterbodies in the HUC-12 subwatershed.

Table 8 Determination of Analysis Areas for TMDL Development

HUC-12 Subwatershed (06010103____)	Impaired Waterbody	Area
0102	Town Creek	HUC-12
0103	Roan Creek	DA
0104	Campbell Creek	DA
0206	Sink Branch	DA
0501	Campbell Branch	DA
0504	Sinking Creek	HUC-12
0505	Cash Hollow Creek Knob Creek	HUC-12
0508	Boones Creek	HUC-12

Note: HUC-12 = HUC-12 Subwatershed
DA = Waterbody Drainage Area

8.3 TMDL Analysis Methodology

TMDLs for the Watauga Watershed were developed using load duration curves for analysis of impaired HUC-12 subwatersheds or specific waterbody drainage areas. A load duration curve (LDC) is a cumulative frequency graph that illustrates existing water quality conditions (as represented by loads calculated from monitoring data), how these conditions compare to desired targets, and the portion of the waterbody flow regime represented by these existing loads. Load duration curves are considered to be well suited for analysis of periodic monitoring data collected by grab sample. LDCs were developed at monitoring site locations in impaired waterbodies and an overall load reduction calculated to meet E. coli targets according to the methods described in Appendix C.

8.4 Critical Conditions and Seasonal Variation

The critical condition for non-point source E. coli loading is an extended dry period followed by a rainfall runoff event. During the dry weather period, E. coli bacteria builds up on the land surface, and is washed off by rainfall. The critical condition for point source loading occurs during periods of low streamflow when dilution is minimized. Both conditions are represented in the TMDL analysis.

The ten-year period from October 1, 1994 to September 30, 2004 was used to simulate flow. This 10-year period contained a range of hydrologic conditions that included both low and high streamflows. Critical conditions are accounted for in the load duration curve analysis by using the entire period of flow and water quality data available for the impaired waterbodies. In all subwatersheds, water quality data have been collected during most flow ranges. Based on the location of the water quality exceedances on the load duration curves, no one delivery mode for E. coli appears to be dominant (see Section 9.3 and Table 9).

Seasonal variation was incorporated in the load duration curves by using the entire simulation period and all water quality data collected at the monitoring stations. The water quality data were not collected during all seasons.

8.5 Margin of Safety

There are two methods for incorporating MOS in TMDL analysis: a) implicitly incorporate the MOS using conservative model assumptions; or b) explicitly specify a portion of the TMDL as the MOS and use the remainder for allocations. For development of pathogen TMDLs in the Watauga Watershed, an explicit MOS, equal to 10% of the E. coli water quality targets (ref.: Section 5.0), was utilized for determination of WLAs and LAs:

Instantaneous Maximum (Tier II):	MOS = 49 CFU/100 ml
Instantaneous Maximum (non-Tier II):	MOS = 94 CFU/100 ml
30-Day Geometric Mean:	MOS = 13 CFU/100 ml

8.6 Determination of TMDLs

E. coli load reductions were calculated for impaired segments in the Watauga Watershed using Load Duration Curves to evaluate compliance with the maximum target concentrations according to the procedure in Appendix C. When sufficient data were available, load reductions were also developed to achieve compliance with the 30-day geometric mean target concentrations. Both instream load reductions (where applicable) for a particular waterbody were compared and the largest required load reduction was selected as the TMDL. These TMDL load reductions for impaired segments are shown in Table 9 and are applied according to the areas specified in Table 8. In cases where the geometric mean could not be developed, it is assumed that achieving the load reduction based on the maximum target concentrations should result in attainment of the geometric mean criteria.

8.7 Determination of WLAs & LAs

WLAs for MS4s and LAs for precipitation induced sources of E. coli loading were determined according to the procedures in Appendix C. These allocations represent the higher load reductions necessary to achieve instream targets <u>after application of the explicit MOS</u>. WLAs for existing WWTFs are equal to their existing NPDES permit limits. Since WWTF permit limits require that E. coli concentrations must comply with water quality criteria (TMDL targets) at the point of discharge and recognition that loading from these facilities are generally small in comparison to other loading sources, further reductions were not considered to be warranted. WLAs for CAFOs and LAs for “other direct sources” (non-precipitation induced) are equal to zero. WLAs, & LAs are summarized in Table 9.

Table 9 TMDLs, WLAs, & LAs for Impaired Subwatersheds and Drainage Areas in the Watauga Watershed

HUC-12 Subwatershed (06010103__) or Drainage Area	Impaired Waterbody Name	Impaired Waterbody ID	TMDL	WLAs				LAs	
				WWTFs [a,b]		CAFOs	MS4s [c]	Precipitation Induced Nonpoint Sources	Other Direct Sources [d]
				Monthly Avg.	Daily Max.				
			[% Red.]	[CFU/day]	[CFU/day]	[CFU/day]	[% Red.]	[% Red.]	[CFU/day]
0102	Town Creek	TN06010103034 – 0300	0	5.723×10^{9}	4.274×10^{10}	NA	NA	0	0
DA	Roan Creek	TN06010103034 – 2000	42.3	5.723×10^{9}	4.274×10^{10}	0	NA	48.1	0
DA	Campbell Creek	TN06010103037 – 0400	0	NA	NA	NA	NA	0	0
DA	Sink Branch	TN06010103020T – 0200	>61.1	NA	NA	NA	NA	>65.0	0
DA	Campbell Branch	TN06010103008 – 0200	>61.1	7.631×10^{7}	5.699×10^{8}	NA	>65.0	>65.0	0
0504	Sinking Creek	TN06010103046 – 1000	>68.8	NA	NA	NA	>71.8	>71.8	0
0505	Cash Hollow Creek	TN06010103035 - 0100	67.9	NA	NA	NA	71.2	71.2	0
	Knob Creek	TN06010103035 – 1000							
0508	Boones Creek	TN06010103006 – 1000	>59.6	NA	NA	NA	>63.7	>63.7	0

Notes: NA = Not Applicable.

a. Future WWTFs must meet instream water quality standards at the point of discharge as specified in their NPDES permit.

b. The WLAs listed apply to NPDES permitted discharges from WWTFs only. Pathogen loading due to collection system failure is considered to be unpermitted point source loading from the municipal WWTF. With respect to pathogen loading from leaking collection systems, a WLA of zero is assigned. It is recognized, however, that a WLA of 0 CFU/day may not be practical. For these unpermitted sources, the WLA is interpreted to mean a reduction in pathogen loading to the maximum extent practicable, consistent with the requirement that these sources not contribute to a violation of the water quality standard for E. coli.

c. Applies to any MS4 discharge loading in the subwatershed.

d. The objective for all “other direct sources” is a load allocation of zero. It is recognized, however, that for leaking septic systems a LA of 0 CFU/day may not be practical. For these sources, the LA is interpreted to mean a reduction in pathogen loading to the maximum extent practicable, consistent with the requirement that these sources not contribute to a violation of the water quality standard for E. coli.

9.0 IMPLEMENTATION PLAN

The TMDLs, WLAs, and LAs developed in Section 8 are intended to be the first phase of a long-term effort to restore the water quality of impaired waterbodies in the Watauga Watershed through reduction of excessive pathogen loading. Adaptive management methods, within the context of the State's rotating watershed management approach, will be used to modify TMDLs, WLAs, and LAs as required to meet water quality goals.

9.1 Point Sources

9.1.1 NPDES Regulated Municipal and Industrial Wastewater Treatment Facilities

All present and future discharges from industrial and municipal wastewater treatment facilities are required to be in compliance with the conditions of their NPDES permits at all times, including elimination of bypasses and overflows. In Tennessee, permit limits for treated sanitary wastewater require compliance with coliform water quality standards (ref: Section 5.0) prior to discharge. No additional reduction is required. WLAs for WWTFs are derived from facility design flows and permitted E. coli limits and are expressed as average loads in CFU per day.

9.1.2 NPDES Regulated Municipal Separate Storm Sewer Systems (MS4s)

For existing and future regulated discharges from municipal separate storm sewer systems, WLAs will be implemented through Phase I & II MS4 permits. These permits will require the development and implementation of a Storm Water Management Program (SWMP) that will reduce the discharge of pollutants to the "maximum extent practicable" and not cause or contribute to violations of State water quality standards. The *NPDES General Permit for Discharges from Small Municipal Separate Storm Sewer Systems* (TDEC, 2003) was issued on February 27, 2003 and requires SWMPs to include six minimum control measures:

- Public education and outreach on storm water impacts
- Public involvement/participation
- Illicit discharge detection and elimination
- Construction site storm water runoff control
- Post-construction storm water management in new development and re-development
- Pollution prevention/good housekeeping for municipal operations

For discharges into impaired waters, the Phase II MS4 General Permit (ref: http://www.state.tn.us/environment/wpc/stormh2o/MS4II.php) requires that SWMPs include a section describing how discharges of pollutants of concern will be controlled to ensure that they do not cause or contribute to instream exceedances of water quality standards. Specific measures and BMPs to control pollutants of concern must also be identified. In addition, MS4s must implement the WLA provisions of an applicable TMDL and <u>describe methods to evaluate whether storm water controls are adequate to meet the WLA</u>.

In order to evaluate SWMP effectiveness and demonstrate compliance with specified WLAs, MS4s must develop and implement appropriate monitoring programs. Instream monitoring, at locations selected to best represent the effectiveness of BMPs, must include analytical monitoring of pollutants of concern. A detailed plan describing the monitoring program must be submitted to the Division of Water Pollution Control Johnson City Field Office within 12 months of the approval date of this TMDL. Implementation of the monitoring program must commence within 6 months of plan approval by the Field Office. The monitoring program shall comply with the monitoring, recordkeeping, and reporting requirements of NPDES General Permit for Discharges from Small Municipal Separate Storm Sewer Systems (TDEC, 2003).

9.1.3 NPDES Regulated Concentrated Animal Feeding Operations (CAFOs)

WLAs provided to CAFOs will be implemented through NPDES Permit No. TNA000000, General NPDES Permit for *Class II Concentrated Animal Feeding Operation* or the facility's individual permit. Among the provisions of the general permit are:

- Development and implementation of a site-specific Nutrient Management Plan (NMP) that:
    - Includes best management practices (BMPs) and procedures necessary to implement applicable limitations and standards;
    - Ensures adequate storage of manure, litter, and process wastewater including provisions to ensure proper operation and maintenance of the storage facilities.
    - Ensures proper management of mortalities (dead animals);
    - Ensures diversion of clean water, where appropriate, from production areas;
    - Identifies protocols for manure, litter, wastewater and soil testing;
    - Establishes protocols for land application of manure, litter, and wastewater;
    - Identifies required records and record maintenance procedures.

  The NMP must submitted to the State for approval and a copy kept on-site.

- Requirements regarding manure, litter, and wastewater land application BMPs.

- Requirements for the design, construction, operation, and maintenance of CAFO liquid waste management systems that are constructed, modified, repaired, or placed into operation after April 13, 2006. The final design plans and specifications for these systems must meet or exceed standards in the NRCS Field Office Technical Guide and other guidelines as accepted by the Departments of Environment and Conservation, or Agriculture.

Provisions of individual CAFO permits are similar. NPDES Permit No. TNA000000, *Class II Concentrated Animal Feeding Operation General Permit* is available on the TDEC website at http://www.state.tn.us/environment/wpc/programs/cafo/.

9.2 Nonpoint Sources

The Tennessee Department of Environment & Conservation (TDEC) has no direct regulatory authority over most nonpoint source discharges. Reductions of pathogen loading from nonpoint sources (NPS) will be achieved using a phased approach. Voluntary, incentive-based mechanisms will be used to implement NPS management measures in order to assure that measurable reductions in pollutant loadings can be achieved for the targeted impaired waters. Cooperation and active participation by the general public and various industry, business, and environmental groups is critical to successful implementation of TMDLs. There are links to a number of publications and information resources on EPA's Nonpoint Source Pollution web page (http://www.epa.gov/owow/nps/pubs.html) relating to the implementation and evaluation of nonpoint source pollution control measures.

TMDL implementation activities will be accomplished within the framework of Tennessee's Watershed Approach (ref: http://www.state.tn.us/environment/wpc/watershed/). The Watershed Approach is based on a five-year cycle and encompasses planning, monitoring, assessment, TMDLs, WLAs/LAs, and permit issuance. It relies on participation at the federal, state, local and nongovernmental levels to be successful.

Local citizen-led and implemented management measures offer the most efficient and comprehensive avenue for reduction of loading rates from nonpoint sources. An excellent example of stakeholder involvement and action for the implementation of the nonpoint source load allocations (LAs) specified in an approved TMDL is described in *Guidance for Development of a Total Maximum Daily Load Implementation Plan for Fecal Coliform Reduction* (SCWA, 2004), prepared by the Sinking Creek Watershed Alliance. This document details the cooperative effort of a number of stakeholders and governmental entities to develop an implementation plan for the restoration of water quality in Sinking Creek, near Johnson City, Tennessee. Plan development was funded, in part, through a TDEC 604(b) grant and a Tennessee Department of Agriculture (TDA) Nonpoint source Program 319 grant. The plan is based on land use and pollutant source identification surveys and considers public education & participation, funding resources, in-stream monitoring, best management practices (BMPs), and stakeholder responsibilities. Recommendations for future activities include verification of chemical/biological findings through Bacteria Source Tracking (BST) research, implementation of appropriate BMPs, post implementation monitoring to verify reduction of pollutant loading.

BMPs have been utilized in the Watauga Watershed to reduce the amount of coliform bacteria transported to surface waters from agricultural sources. These BMPs (e.g., animal waste management systems, waste utilization, stream stabilization, fencing, heavy use area treatment, livestock exclusion, etc.) may have contributed to reductions in in-stream concentrations of coliform bacteria in the Watauga Watershed during the TMDL evaluation period. The TDA keeps a database of BMPs implemented in Tennessee. Those listed in the Watauga Watershed are shown in Figure 9. It is recommended that additional information (e.g., livestock access to streams, manure application practices, etc.) be provided and evaluated to better identify and quantify agricultural sources of coliform bacteria loading in order to minimize uncertainty in future modeling efforts.

It is further recommended that BMPs be utilized to reduce the amount of coliform bacteria transported to surface waters from agricultural sources. Demonstration sites for various types of BMPs should be established, maintained, and evaluated (performance in source reduction) over a period of at least two years prior to recommendations for utilization for subsequent implementation. E. coli sampling and monitoring are recommended during low-flow (baseflow) and storm periods at sites with and without BMPs and/or before and after implementation of BMPs.

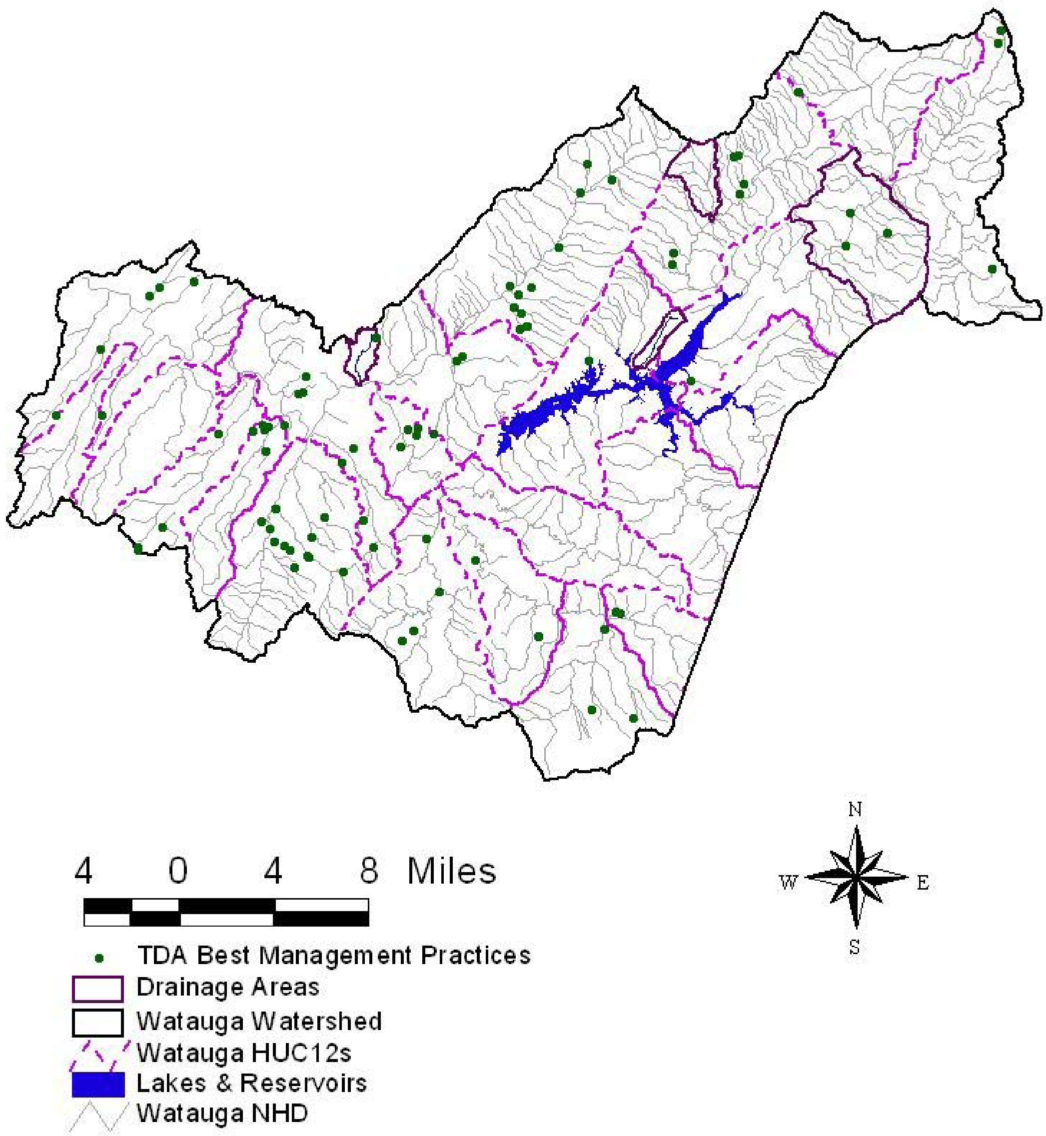

Figure 9. Tennessee Department of Agriculture Best Management Practices located in the Watauga Watershed.

9.3 Application of Load Duration Curves for Implementation Planning

The Load Duration Curve methodology (Appendix C) is a form of water quality analysis and presentation of data that aids in guiding implementation by targeting strategies to appropriate flow conditions. One of the strengths of this method is that it can be used to interpret possible delivery mechanisms of pathogens by differentiating between point and nonpoint problems. The E. coli load duration analysis was utilized for implementation planning. The E. coli load duration curve for each pathogen-impaired subwatershed (Figures C-2 through C-7) was analyzed to determine the frequency with which water quality monitoring data exceed the E. coli target maximum concentration of 941 CFU/100 mL under five flow conditions (low, dry, mid- range, moist, and high). A sample E. coli load duration curve is presented in Figure 10.

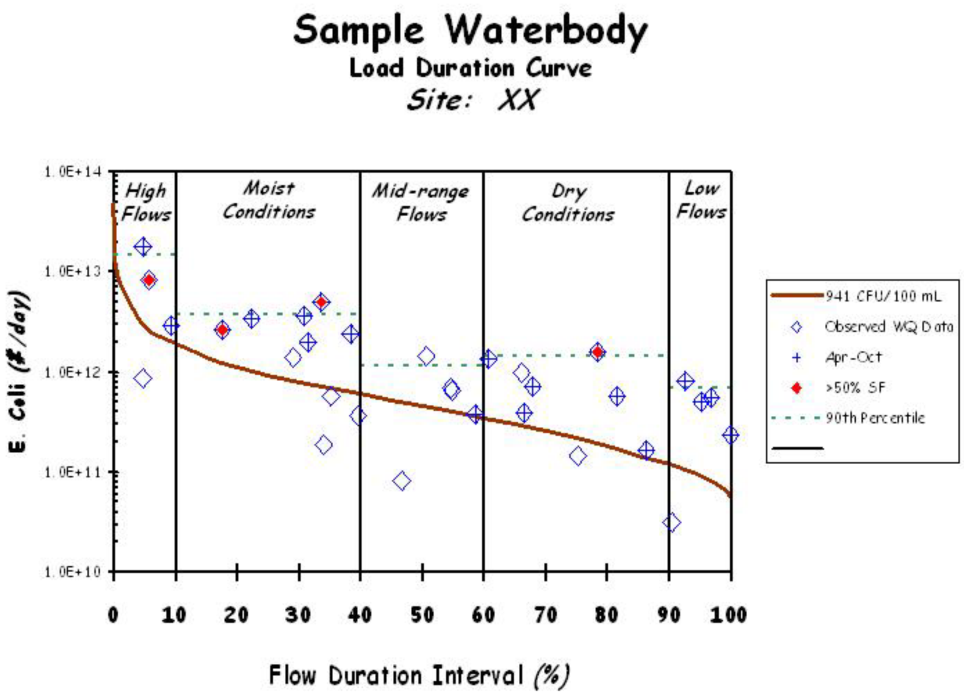

Figure 10. Sample E. Coli Load Duration Curve

Table 10 presents an example of Load Duration analysis statistics for E. coli. Table 11 presents targeted implementation strategies for each source category covering the entire range of flow (Stiles, 2003). Each implementation strategy addresses a range of flow conditions and targets point sources, nonpoint sources, or a combination of each. Results indicate the implementation strategy for all subwatersheds will require BMPs targeting a variety of sources. The implementation strategies listed in Table 11 are a subset of the categories of BMPs and implementation strategies available for application to the pathogen-impaired Watauga subwatersheds for reduction of pathogen loading and mitigation of water quality impairment.

See Appendix C for a detailed discussion of the Load Duration Curve Methodology applied to the Watauga Watershed.

Table 10 Sample Load Duration Curve Summary

Flow Condition		High	Moist	Mid-range	Dry	Low
% Time Flow Exceeded		0-10	10-40	40-60	60-90	90-100
Sample Site	% Samples > 941 CFU/100 mL	75.0	90.0	40.0	87.5	80.0
	Reduction	>61.1	>61.1	>49.7	>61.1	>61.1

Table 11 Example Implementation Strategies

Flow Condition	High	Moist	Mid-range	Dry	Low
% Time Flow Exceeded	0-10	10-40	40-60	60-90	90-100
Municipal NPDES		**L**	**M**	**H**	**H**
Stormwater Management		**H**	**H**	**H**	
SSO Mitigation	**H**	**H**	**M**	**L**	
Collection System Repair		**L**	**M**	**H**	**H**
Septic System Repair		**L**	**M**	**H**	**M**
Livestock Exclusion[1]			**M**	**H**	**H**
Pasture Management/Land Application of Manure[1]	**H**	**H**	**M**	**L**	
Riparian Buffers[1]		**H**	**H**	**H**	
Potential for source area contribution under given hydrologic condition (H: High; M: Medium; L: Low)					

[1] Example Best Management Practices (BMPs) for Agricultural Source reduction. Actual BMPs applied may vary.

9.4 Additional Monitoring

Documenting progress in reducing the quantity of pathogens entering the Watauga Watershed is an essential element of the TMDL Implementation Plan. Additional monitoring and assessment activities are recommended to determine whether implementation of TMDLs, WLAs, & LAs in tributaries and upstream reaches will result in achievement of instream water quality targets for E. coli. Future monitoring activities should be representative of all seasons and a full range of flow and meteorological conditions. Monitoring activities should also be adequate to assess water quality using the 30-day geometric mean standard.

Tennessee's watershed management approach specifies a five-year cycle for planning and assessment. Each watershed will be examined (or re-examined) on a rotating basis. Generally, in years two and three of the five-year cycle, water quality data are collected in support of water quality assessment (including TMDL development) and planning activities. Therefore, a watershed TMDL is developed one to two years prior to commencement of the next cycle's monitoring period.

Additional monitoring and assessment activities are recommended for all impaired waterbodies in the Watauga Watershed. A load reduction could not be developed for Campbell Creek due to insufficient monitoring data. Additional monitoring is recommended to allow for either development of a TMDL or delisting.

Fewer than 6 samples were taken at any one location in four of the remaining impaired waterbodies (Boones Creek, Campbell Branch, Sink Branch, Knob Creek). Once additional monitoring representing all seasons and a full range of flow and meteorological conditions has been obtained, the required load reductions may be revised.

An intensive short-term sampling effort (e.g. 10 samples in 30 days) was undertaken in two of the impaired waterbodies (Cash Hollow Creek, Sinking Creek). While this sampling allowed for the 30-day geometric mean to be calculated, no other sampling events have occurred in the past five years and this sampling was not representative of all seasons and flow conditions. Once additional monitoring representing all seasons and a full range of flow and meteorological conditions has been obtained, the required load reductions may be revised.

Analysis of monitoring data for Town Creek and Roan Creek suggests that improvement in water quality has occurred since the previous TMDL was approved in 2001. At this time, delisting is suggested for Town Creek (see Appendix E).

9.5 Source Identification

An important aspect of pathogen load reduction activities is the accurate identification of the actual sources of pollution. In cases where the sources of pathogen impairment are not readily apparent, Microbial Source Tracking (MST) is one approach to determining the sources of fecal pollution and pathogens affecting a waterbody. Those methods that use bacteria as target organisms are also known as Bacterial Source Tracking (BST) methods. This technology is recommended for source identification in pathogen impaired waterbodies.

Bacterial Source Tracking is a collective term used for various emerging biochemical, chemical, and molecular methods that have been developed to distinguish sources of human and non-human fecal pollution in environmental samples (Shah, 2004). In general, these methods rely on genotypic (also known as “genetic fingerprinting”), or phenotypic (relating to the physical characteristics of an organism) distinctions between the bacteria of different sources. Three primary genotypic techniques are available for BST: ribotyping, pulsed field gel electrophoresis (PFGE), and polymerase chain reaction (PCR). Phenotypic techniques generally involve an antibiotic resistance analysis (Hyer, 2004).

The USEPA has published a fact sheet that discusses BST methods and presents examples of BST application to TMDL development and implementation (USEPA, 2002b). Various BST projects and descriptions of the application of BST techniques used to guide implementation of effective BMPs to remove or reduce fecal contamination are presented. The fact sheet can be found on the following EPA website: http://www.epa.gov/owm/mtb/bacsortk.pdf.

A multi-disciplinary group of researchers is developing and testing a series of different microbial assay methods based on real-time PCR to detect fecal bacterial concentrations and host sources in water samples (McKay, 2005). The assays have been used in a study of fecal contamination and have proven useful in identification of areas where cattle represent a significant fecal input and in development of BMPs. It is expected that these types of assays could have broad applications in monitoring fecal impacts from Animal Feeding Operations, as well as from wildlife and human sources. Other BST projects have been conducted or are currently in progress throughout the state of Tennessee, as presented in sessions of the Thirteenth Tennessee Water Resources Symposium (Lawrence, 2003) and the Fifteenth Tennessee Water Resources Symposium (Bailey, 2005; Baldwin, 2005; Farmer, 2005).

9.6 Evaluation of TMDL Implementation Effectiveness

The effectiveness of the TMDL will be assessed within the context of the State's rotating watershed management approach. Watershed monitoring and assessment activities will provide information by which the effectiveness of pathogen loading reduction measures can be evaluated. Additional monitoring data, ground-truthing activities, and bacterial source identification actions are recommended to enable implementation of particular types of BMPs to be directed to specific areas in impaired subwatersheds. This will optimize utilization of resources to achieve maximum reductions in pathogen loading. These TMDLs will be re-evaluated during subsequent watershed cycles and revised as required to assure attainment of applicable water quality standards.

10.0 PUBLIC PARTICIPATION

In accordance with 40 CFR §130.7, the proposed pathogen TMDLs for the Watauga Watershed was placed on Public Notice for a 35-day period and comments solicited. Steps that were be taken in this regard include:

1) Notice of the proposed TMDLs was posted on the Tennessee Department of Environment and Conservation website. The announcement invited public and stakeholder comment and provided a link to a downloadable version of the TMDL document.

2) Notice of the availability of the proposed TMDLs (similar to the website announcement) was included in one of the NPDES permit Public Notice mailings which is sent to approximately 90 interested persons or groups who have requested this information.

3) Letters were sent to WWTFs located in E. coli-impaired subwatersheds or drainage areas in the Watauga Watershed, permitted to discharge treated effluent containing pathogens, advising them of the proposed TMDLs and their availability on the TDEC website. The letters also stated that a copy of the draft TMDL document would be provided on request. A letter was sent to the following facilities:

    Keenburg Elementary School (TN0023736)
    Mountain City STP (TN0024945)

4) A draft copy of the proposed TMDL was sent to those MS4s that are wholly or partially located in pathogen-impaired subwatersheds. A draft copy was sent to the following entities:

City of Elizabethton, Tennessee (TNS075281)
City of Johnson City, Tennessee (TNS075370)
City of Jonesborough, Tennessee (TNS075728)
Carter County, Tennessee (TNS075124) – pending
Sullivan County, Tennessee (TNS075671)
Washington County, Tennessee (TNS075787)
Tennessee Dept. of Transportation (TNS077585)

5) A letter was sent to water quality partners in the Watauga Watershed advising them of the proposed pathogen TMDLs and their availability on the TDEC website. The letter also stated that a written copy of the draft TMDL document would be provided upon request. A letter was sent to the following partners:

Natural Resources Conservation Service
Tennessee Valley Authority
United States Forest Service
Tennessee Department of Agriculture
Tennessee Wildlife Resources Agency
North Carolina's Basinwide Planning Program
Boone Watershed Partnership
The Nature Conservancy

11.0 FURTHER INFORMATION

Further information concerning Tennessee's TMDL program can be found on the Internet at the Tennessee Department of Environment and Conservation website:

http://www.state.tn.us/environment/wpc/tmdl/

Technical questions regarding this TMDL should be directed to the following members of the Division of Water Pollution Control staff:

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APPENDIX A

Land Use Distribution in the Watauga Watershed

Table A-1. MRLC Land Use Distribution of Watauga Subwatersheds

Land Use	HUC-12 Subwatershed (06010103__) or Drainage Area					
	0102		Roan Creek DA		Campbell Creek DA	
	[acres]	[%]	[acres]	[%]	[acres]	[%]
Bare Rock/Sand/Clay	14.9	0.1	9.3	0.1	0.7	0.0
Deciduous Forest	6,442.8	34.4	6,220.2	41.9	671.6	24.3
Emergent Herbaceous Wetlands	1.6	0.0	0.4	0.0	0.0	0.0
Evergreen Forest	3,444.0	18.4	2,339.2	15.8	675.0	24.4
High Intensity Commercial/ Industrial/Transp.	265.8	1.4	4.7	0.0	0.0	0.0
High Intensity Residential	90.1	0.5	0.0	0.0	0.0	0.0
Low Intensity Residential	561.8	3.0	10.2	0.1	0.0	0.0
Mixed Forest	3,917.5	20.9	2,918.7	19.7	1,118.2	40.4
Open Water	3.1	0.0	0.9	0.0	0.0	0.0
Other Grasses (Urban/recreation; e.g. parks)	166.4	0.9	0.0	0.0	0.0	0.0
Pasture/Hay	3,092.2	16.5	2,371.6	16.0	277.3	10.0
Quarries/Strip Mines/Gravel Pits	0.0	0.0	0.0	0.0	0.0	0.0
Row Crops	705.9	3.8	946.3	6.4	22.7	0.8
Woody Wetlands	8.5	0.0	8.5	0.1	0.4	0.0
Total	18,714.4	100.0	14,830.0	100.0	2,765.9	100.0

Table A-1 (Cont.). MRLC Land Use Distribution of Watauga Subwatersheds

Land Use	HUC-12 Subwatershed (06010103__) or Drainage Area					
	Sink Branch DA		Campbell Branch DA		0504	
	[acres]	[%]	[acres]	[%]	[acres]	[%]
Bare Rock/Sand/Clay	0.4	0.1	2.0	0.2	17.3	0.2
Deciduous Forest	459.5	50.8	543.5	40.8	3348.8	37.6
Emergent Herbaceous Wetlands	0.0	0.0	0.4	0.0	0.0	0.0
Evergreen Forest	83.2	9.2	136.6	10.3	1084.8	12.2
High Intensity Commercial/ Industrial/Transp.	0.0	0.0	22.0	1.7	305.6	3.4
High Intensity Residential	0.0	0.0	5.3	0.4	177.9	2.0
Low Intensity Residential	0.0	0.0	193.7	14.5	1480.5	16.6
Mixed Forest	321.8	35.6	200.6	15.1	1295.2	14.5
Open Water	1.1	0.1	1.1	0.1	2.0	0.0
Other Grasses (Urban/recreation; e.g. parks)	0.0	0.0	37.1	2.8	271.8	3.1
Pasture/Hay	35.1	3.9	141.0	10.6	798.2	9.0
Quarries/Strip Mines/Gravel Pits	0.0	0.0	0.0	0.0	0.0	0.0
Row Crops	3.3	0.4	47.1	3.5	110.8	1.2
Woody Wetlands	0.0	0.0	1.3	0.1	8.9	0.1
Total	904.5	100.0	1,331.9	100.0	8,901.8	100.0

Table A-1 (Cont.). MRLC Land Use Distribution of Watauga Subwatersheds

Land Use	HUC-12 Subwatershed (06010103__) or Drainage Area			
	0507		0508	
	[acres]	[%]	[acres]	[%]
Bare Rock/Sand/Clay	76.3	0.6	57.8	0.7
Deciduous Forest	3,197.6	23.5	1,540.1	17.9
Emergent Herbaceous Wetlands	0.2	0.0	0.0	0.0
Evergreen Forest	1,790.3	13.2	1,093.5	12.7
High Intensity Commercial/ Industrial/Transp.	1,014.6	7.5	57.2	0.7
High Intensity Residential	481.5	3.5	4.4	0.1
Low Intensity Residential	2,391.2	17.6	166.6	1.9
Mixed Forest	1,378.0	10.1	965.0	11.2
Open Water	20.0	0.1	0.0	0.0
Other Grasses (Urban/recreation; e.g. parks)	428.8	3.2	80.3	0.9
Pasture/Hay	2,434.6	17.9	4,322.3	50.2
Quarries/Strip Mines/Gravel Pits	39.4	0.3	0.0	0.0
Row Crops	307.8	2.3	307.1	3.6
Woody Wetlands	28.9	0.2	18.0	0.2
Total	13,589.0	100.0	8,612.3	100.0

APPENDIX B

Water Quality Monitoring Data

There are a number of water quality monitoring stations that provide data for waterbodies identified as impaired for pathogens in the Watauga Watershed. The location of these monitoring stations is shown in Figure 5. Monitoring data recorded by TDEC at these stations are tabulated in Table B-1.

Table B-1. TDEC Water Quality Monitoring Data – Watauga Subwatersheds

Monitoring Station	Date	E. Coli [cts./100 mL]
BOONE001.7WN	8/21/01	488
	11/14/01	488
	6/4/02	>2419
BOONE003.7WN	8/21/01	727
	11/14/01	1203
	6/4/02	1986
BOONE007.6WN	8/21/01	461
	11/14/01	1986
	6/4/02	>2419
CAMPB000.3CT	8/7/01	488
	11/6/01	>2419
	2/5/02	1986
	5/7/02	>2419
CAMPB000.4JO	7/10/01	548
	10/23/01	162
	1/9/02	3
	5/14/02	12
CHOLL000.3WN	9/9/99	159
	3/7/00	185
	3/9/00	162
	3/14/00	222
	3/16/00	>2419
	3/21/00	579
	3/23/00	114
	3/28/00	114
	3/29/00	613
	4/3/00	1553
	4/4/00	687

Table B-1 (Cont.). TDEC Water Quality Monitoring Data – Watauga Subwatersheds

Monitoring Station	Date	E. Coli [cts./100 mL]
CHOLL000.5WN	9/9/99	99
	3/7/00	46
	3/9/00	74
	3/14/00	93
	3/16/00	93
	3/21/00	411
	3/23/00	201
	3/28/00	488
	3/28/00	84
	4/4/00	816
	4/30/00	1733
CHOLL001.5WN	9/9/99	365
	3/7/00	20
	3/9/00	214
	3/14/00	93
	3/16/00	65
	3/21/00	299
	3/23/00	113
	3/28/00	189
	3/29/00	133
	4/3/00	1300
	4/4/00	1203
	9/9/00	365
CHOLL002.7WN	9/9/99	613
	3/7/00	50
	3/9/00	46
	3/14/00	50
	3/16/00	55
	3/21/00	157
	3/23/00	38
	3/28/00	185
	3/30/00	387
	4/3/00	727
	4/4/00	1300
	9/9/00	613

Table B-1 (Cont.). TDEC Water Quality Monitoring Data – Watauga Subwatersheds

Monitoring Station	Date	E. Coli [cts./100 mL]
FORGE000.5JO	7/18/01	197
	8/8/01	139
	9/5/01	173
	10/10/01	106
	11/7/01	1
	12/5/01	15
	1/16/02	4
	2/6/02	13
	3/13/02	14
	4/23/02	4
	5/8/02	1
	6/11/02	1
KNOB001.0WN	8/21/01	1553
	11/14/01	93
	6/4/02	435
KNOB003.7WN	8/21/01	>2419
	11/14/01	727
	6/4/02	613
KNOB005.8WN	8/21/01	1986
	11/14/01	>2419
	6/4/02	1986
ROAN007.5JO	7/18/01	214
	8/8/01	250
	9/5/01	31
	10/10/01	14
	11/7/01	1
	12/5/01	1
	1/16/02	4
	2/6/02	4
	3/13/02	<1
	4/23/02	210
	5/8/02	25
	6/11/02	7

Table B-1 (Cont.). TDEC Water Quality Monitoring Data – Watauga Subwatersheds

Monitoring Station	Date	E. Coli [cts./100 mL]
ROAN011.6JO	7/18/01	110
	8/8/01	52
	9/5/01	126
	10/10/01	19
	11/7/01	13
	12/5/01	27
	1/16/02	28
	2/6/02	6
	3/13/02	4
	4/23/02	2
	5/8/02	23
	6/11/02	22
ROAN016.4JO	11/18/98	205
	2/9/99	21
	11/15/00	260
	2/27/01	10
	5/15/01	135
	7/18/01	921
	8/8/01	99
	9/5/01	87
	10/10/01	30
	11/7/01	8
	12/5/01	921
	1/16/02	35
	2/6/02	18
	3/13/02	32
	4/23/02	94
	5/8/02	7
	6/11/02	792
ROAN017.9JO	11/18/98	31
	2/9/99	85
	11/15/00	18
	5/15/01	436

Table B-1 (Cont.). TDEC Water Quality Monitoring Data – Watauga Subwatersheds

Monitoring Station	Date	E. Coli [cts./100 mL]
ROAN017.9JO (continued)	7/18/01	579
	8/8/01	548
	9/5/01	88
	10/10/01	10
	11/7/01	5
	12/5/01	5
	1/16/02	39
	2/6/02	6
	3/13/02	7
	4/23/02	105
	5/8/02	7
	6/11/02	25
SINK000.7JO	9/4/01	>2419
	3/12/02	921
	6/5/02	>2419
SINKI000.6CT	9/9/99	579
	3/7/00	130
	3/9/00	80
	3/14/00	192
	3/16/00	102
	3/21/00	210
	3/23/00	44
	3/28/00	115
	3/30/00	147
	4/3/00	1553
	4/4/00	2419
SINKI001.1CT	9/9/99	378
	3/7/00	74
	3/9/00	54
	3/14/00	206
	3/16/00	72
	3/21/00	123
	3/23/00	37
	3/28/00	115
	3/29/00	101

Table B-1 (Cont.). TDEC Water Quality Monitoring Data – Watauga Subwatersheds

Monitoring Station	Date	E. Coli [cts./100 mL]
SINKI001.1CT (continued)	4/3/00	1203
	4/4/00	>2419
	9/9/00	378
SINKI002.9WN	9/9/99	727
	3/7/00	15
	3/9/00	11
	3/14/00	12
	3/16/00	72
	3/21/00	69
	3/23/00	9
	3/28/00	15
	3/29/00	15
	4/2/00	687
	4/4/00	727
	9/13/00	727
SINKI004.5WN	9/9/99	157
	3/7/00	59
	3/9/00	124
	3/14/00	31
	3/16/00	23
	3/21/00	111
	3/23/00	6
	3/28/00	6
	3/29/00	13
	4/3/00	231
	4/4/00	687
	9/9/00	157
SINKI005.5WN	9/9/99	146
	3/7/00	5
	3/9/00	16
	3/14/00	1
	3/16/00	2

Table B-1 (Cont.). TDEC Water Quality Monitoring Data – Watauga Subwatersheds

Monitoring Station	Date	E. Coli [cts./100 mL]
SINKI005.5WN (continued)	3/21/00	13
	3/23/00	5
	3/28/00	5
	3/29/00	6
	4/3/00	141
	4/4/00	345
TOWN000.9JO	11/15/00	29
	5/15/01	186
	7/18/01	81
	8/8/01	84
	9/5/01	11
	10/10/01	5
	11/7/01	2
	12/5/01	1
	1/16/02	11
	2/6/02	4
	3/13/02	<1
	4/23/02	2
	5/8/02	25
	6/11/02	24
TOWN1T0.3JO	7/18/01	34
	10/10/01	<1
	4/23/02	<1

APPENDIX C

Load Duration Curve Development
and
Determination of Required Load Reductions

The TMDL process quantifies the amount of a pollutant that can be assimilated in a waterbody, identifies the sources of the pollutant, and recommends regulatory or other actions to be taken to achieve compliance with applicable water quality standards based on the relationship between pollution sources and in-stream water quality conditions. A TMDL can be expressed as the sum of all point source loads (Waste Load Allocations), nonpoint source loads (Load Allocations), and an appropriate margin of safety (MOS) that takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

$$\text{TMDL} = \Sigma \text{ WLAs} + \Sigma \text{ LAs} + \text{MOS}$$

The objective of a TMDL is to allocate loads among all of the known pollutant sources throughout a watershed so that appropriate control measures can be implemented and water quality standards achieved. 40 CFR §130.2 (i) states that TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measure.

C.1 Development of TMDLs

E. coli TMDLs, WLAs, and LAs were developed for impaired subwatersheds and drainage areas in the Watauga River Watershed using Load Duration Curves (LDCs) to determine the reduction in pollutant loading required to decrease existing, instream E. coli concentrations to target levels. TMDLs are expressed as required percent reductions in pollutant loading.

C.1.1 Development of Flow Duration Curves

A flow duration curve is a cumulative frequency graph, constructed from historic flow data at a particular location, that represents the percentage of time a particular flow rate is equaled or exceeded. Flow duration curves are developed for a waterbody from daily discharges of flow over a period of record. In general, there is a higher level of confidence that curves derived from data over a long period of record correctly represent the entire range of flow. The preferred method of flow duration curve computation uses daily mean data from USGS continuous-record stations located on the waterbody of interest. For ungaged streams, alternative methods must be used to estimate daily mean flow. These include: 1) regression equations (using drainage area as the independent variable) developed from continuous record stations in the same ecoregion; 2) drainage area extrapolation of data from a nearby continuous-record station of similar size and topography; and 3) calculation of daily mean flow using a dynamic computer model, such as the Loading Simulation Program C++ (LSPC).

Flow duration curves for impaired waterbodies in the Watauga River Watershed were derived from LSPC hydrologic simulations based on parameters derived from calibration at USGS Station No. 03479000, located on the Watauga River near Sugar Grove, North Carolina, in the Watauga watershed (see Appendix D for details of calibration). For example, a flow-duration curve for Roan Creek at RM 16.4 was constructed using simulated daily mean flow for the period from 10/1/94 through 9/31/04 (RM 16.4 corresponds to the location of monitoring station ROAN016.4JO). This flow duration curve is shown in Figure C-1 and represents the cumulative distribution of daily discharges arranged to show percentage of time specific flows were exceeded during the period of record (the highest daily mean flow during this period is exceeded 0% of the time and the lowest daily mean flow is equaled or exceeded 100% of the time). Flow duration curves for other impaired waterbodies were derived using a similar procedure.

C.1.2 Development of Load Duration Curves and Determination of TMDLs

When a water quality target concentration is applied to the flow duration curve, the resulting load duration curve (LDC) represents the allowable pollutant loading in a waterbody over the entire range of flow. Pollutant monitoring data, plotted on the LDC, provides a visual depiction of stream water quality as well as the frequency and magnitude of any exceedances. Load duration curve intervals can be grouped into several broad categories or zones, in order to provide additional insight about conditions and patterns associated with the impairment. For example, the duration curve could be divided into five zones: high flows (exceeded 0-10% of the time), moist conditions (10-40%), median or mid-range flows (40-60%), dry conditions (60-90%), and low flows (90-100%). Impairments observed in the low flow zone typically indicate the influence of point sources, while those further left on the LDC (representing zones of higher flow) generally reflect potential nonpoint source contributions (Stiles, 2003).

E. coli load duration curves for impaired waterbodies in the Watauga River Watershed were developed from the flow duration curves developed in Section C.1.1, E. coli target concentrations, and available water quality monitoring data. Load duration curves and required load reductions were developed using the following procedure (Roan Creek is shown as an example):

1. A target load-duration curve (LDC) was generated for Roan Creek by applying the E. coli target concentration of 487 CFU/100 mL to each of the ranked flows used to generate the flow duration curve (ref.: Section D.1) and plotting the results. The E. coli target maximum load corresponding to each ranked daily mean flow is:

   $(\text{Target Load})_{\text{Roan Creek}} = (487 \text{ CFU/100 mL}) \times (Q) \times (UCF)$

   where: Q = daily mean flow
   UCF = the required unit conversion factor

2. Daily loads were calculated for each of the water quality samples collected at monitoring station ROAN016.4JO (ref.: Table B-1) by multiplying the sample concentration by the daily mean flow for the sampling date and the required unit conversion factor. ROAN016.4JO was selected for LDC analysis because it was the monitoring station on Roan Creek with the most exceedances of the target concentration.

   Note: *In order to be consistent for all analyses, the derived daily mean flow was used to compute sampling data loads, even if measured ("instantaneous") flow data was available for some sampling dates.*

   Example – 7/18/01 sampling event:
   Modelled Flow = 45.93 cfs
   Concentration = 921 CFU/100 mL
   Daily Load = 1.03×10^{12} CFU/day

3. Using the flow duration curves developed in C.1.1, the "percent of days the flow was exceeded" (PDFE) was determined for each sampling event. Each sample load was then plotted on the load duration curves developed in Step 1 according to the PDFE. The resulting E. coli load duration curve for is shown in Figure C-3.

4. For cases where the existing load exceeded the target maximum load at a particular PDFE, the reduction required to reduce the sample load to the target load was calculated.

   Example – 7/18/01 sampling event:
   Target Concentration = 487 CFU/100 mL
   Measured Concentration = 921 CFU/100 mL
   Reduction to Target = 47.1%

5. The 90th percentile value for all of the E. coli sampling data at ROAN016.4JO monitoring site was determined. If the 90th percentile value exceeded the target maximum E. coli concentration, the reduction required to reduce the 90th percentile value to the target maximum concentration was calculated (Table C-2).

   Example: *Target Concentration = 487 CFU/100 mL*
   90th Percentile Concentration = 844 CFU/100 mL
   Reduction to Target = 42.3%

6. For cases where five or more samples were collected over a period of not more than 30 consecutive days, the geometric mean E. coli concentration was determined and compared to the target geometric mean E. coli concentration of 126 CFU/100 mL. If the sample geometric mean exceeded the target geometric mean concentration, the reduction required to reduce the sample geometric mean value to the target geometric mean concentration was calculated.

   Example: *Insufficient monitoring data was available for Roan Creek at Mile 16.4*
   Sufficient data was available for Sinking Creek at Mile 0.6
   Sampling Period = 3/7/00 – 4/4/00
   Geometric Mean Concentration = 203.12 CFU/100 mL
   Target Concentration = 126 CFU/100 mL
   Reduction to Target = 44.4%

7. The load reductions required to meet the target maximum (Step 5) and target 30-day geometric mean concentrations (Step 6) of E. coli were compared and the load reduction of the greatest magnitude selected as the TMDL for Roan Creek.

Load duration curves, required load reductions, and TMDLs of other impaired waterbodies were derived in a similar manner and are shown in Figures C-2 through C-7 and Tables C-1 through C-9.

C.2 Development of WLAs & LAs

As previously discussed, a TMDL can be expressed as the sum of all point source loads (WLAs), nonpoint source loads (LAs), and an appropriate margin of safety (MOS) that takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

$$TMDL = \Sigma\ WLAs + \Sigma\ LAs + MOS$$

Expanding the terms:

$$TMDL = [\Sigma WLAs]_{WWTF} + [\Sigma WLAs]_{MS4} + [\Sigma WLAs]_{CAFO} + [\Sigma LAs]_{DS} + [\Sigma LAs]_{SW} + MOS$$

For pathogen TMDLs in each impaired subwatershed or drainage area, WLA terms include:

- $[\Sigma WLAs]_{WWTF}$ is the allowable load associated with discharges of NPDES permitted WWTFs located in impaired subwatersheds or drainage areas. Since NPDES permits for these facilities specify that treated wastewater must meet instream water quality standards at the point of discharge, no additional load reduction is required. WLAs for WWTFs are calculated from the facility design flow and the Monthly Average permit limit.
- $[\Sigma WLAs]_{CAFO}$ is the allowable load for all CAFOs in an impaired subwatershed or drainage area. All wastewater discharges from a CAFO to waters of the state of Tennessee are prohibited, except when either chronic or catastrophic rainfall events cause an overflow of process wastewater from a facility properly designed, constructed, maintained, and operated to contain:
    - All process wastewater resulting from the operation of the CAFO (such as wash water, parlor water, watering system overflow, etc.); plus,
    - All runoff from a 25-year, 24-hour rainfall event for the existing CAFO or new dairy or cattle CAFOs; or all runoff from a 100-year, 24-hour rainfall event for a new swine or poultry CAFO.

  Therefore, a WLA of zero has been assigned to this class of facilities.
- $[\Sigma WLAs]_{MS4}$ is the required load reduction for discharges from MS4s. E. coli loading from MS4s is the result of buildup/wash-off processes associated with storm events.

LA terms include:

- $[\Sigma LAs]_{DS}$ is the allowable E. coli load from “other direct sources”. These sources include leaking septic systems, illicit discharges, and animals access to streams. The LA specified for all sources of this type is zero CFU/day (or to the maximum extent practicable).
- $[\Sigma LAs]_{SW}$ represents the required reduction in E. coli loading from nonpoint sources indirectly going to surface waters from all land use areas (except areas covered by a MS4 permit) as a result of the buildup/wash-off processes associated with storm events.

Since WWTFs discharges must comply with instream water quality criteria (TMDL target) at the point of discharge, $[\Sigma WLAs]_{CAFO} = 0$, and $[\Sigma LAs]_{DS} = 0$, the expression relating TMDLs to precipitation-based point and nonpoint sources may be simplified to:

$$TMDL – MOS = [\Sigma WLAs]_{MS4} + [\Sigma LAs]_{SW}$$

WLAs for MS4s and LAs for precipitation-based nonpoint sources are equal and expressed as the percent reduction in loading required to decrease instream E. coli concentrations to TMDL target values minus MOS. As stated in Section 8.4, an explicit MOS, equal to 10% of the E. coli water quality targets (ref.: Section 5.0), was utilized for determination of the WLAs and LAs:

Instantaneous Maximum (Tier II):

Target – MOS = (487 CFU/100 ml) – 0.1(487 CFU/100 ml)

Target – MOS = 438 CFU/100 ml

Instantaneous Maximum (non-Tier II):

Target – MOS = (941 CFU/100 ml) – 0.1(941 CFU/100 ml)

Target – MOS = 847 CFU/100 ml

30-Day Geometric Mean: Target – MOS = (126 CFU/100 ml) – 0.1(126 CFU/100 ml)

Target – MOS = 113 CFU/100 ml

C.2.1 Determination of WLAs for MS4s & LAs for Precipitation-Based Nonpoint Sources

WLAs for MS4s and LAs for precipitation-based nonpoint sources were developed using methods similar to those described in C.1.2 (again, using Roan Creek as an example):

8. An allocation LDC was generated for Roan Creek by applying the E. coli “target – MOS” concentration of 438 CFU/100 mL to each of the ranked flows used to generate the flow duration curve (ref.: Section D.1) and plotting the results on the target LDC developed in Step 1. The E. coli target maximum allocated load corresponding to each ranked daily mean flow is:

   $(\text{Target Load - MOS})_{\text{Roan Creek}}$ = (438 CFU/100 mL) x (Q) x (UCF)

   where: Q = daily mean flow
   UCF = the required unit conversion factor

9. For cases where the existing load exceeded the “target maximum load – MOS” at a particular PDFE, the reduction required to reduce the sample load to the “target – MOS” load was calculated.

   Example – 7/18/01 sampling event:
   Target Concentration -- MOS = 438 CFU/100 mL
   Measured Concentration = 921 CFU/100 mL
   Reduction to Target -- MOS = 52.4%

10. If the 90th percentile value for all of the E. coli sampling data at ROAN016.4JO monitoring site (calculated in Step 5) exceeded the “target maximum – MOS” E. coli concentration, the reduction required to reduce the 90th percentile value to the “target maximum – MOS” concentration was calculated (Table C-2).

    Example: *Target Concentration -- MOS = 438 CFU/100 mL*
    90th Percentile Concentration = 844 CFU/100 mL
    Reduction to Target -- MOS = 48.1%

11. For cases where five or more samples were collected over a period of not more than 30 consecutive days, the geometric mean E. coli concentration was determined and compared to the "target geometric mean E. coli concentration – MOS" of 113 CFU/100 mL. If the sample geometric mean exceeded the "target geometric mean – MOS" concentration, the reduction required to reduce the sample geometric mean value to the "target geometric mean – MOS" concentration was calculated.

    Example: *Insufficient monitoring data was available for Roan Creek at Mile 16.4*
    Sufficient data was available for Sinking Creek at Mile 0.6
    Sampling Period = 3/7/00 – 4/4/00
    Geometric Mean Concentration = 203.12 CFU/100 mL
    Target Concentration -- MOS = 113 CFU/100 mL
    Reduction to Target -- MOS = 48.0%

12. The load reductions required to meet the "target maximum – MOS" (Step 10) and "target 30-day geometric mean – MOS" concentrations (Step 11) of E. coli were compared and the load reduction of the greatest magnitude selected as the WLA for MS4s and/or LA for precipitation-based nonpoint sources for Roan Creek.

Load duration curves, required load reductions, WLAs for MS4s, and LAs for precipitation-based nonpoint sources of other impaired waterbodies were derived in a similar manner and are shown in Figures C-2 through C-7 and Tables C-2 through C-9. TMDLs, WLAs, & LAs for impaired subwatersheds and drainage areas in the Watauga River Watershed are summarized in Table C-10.

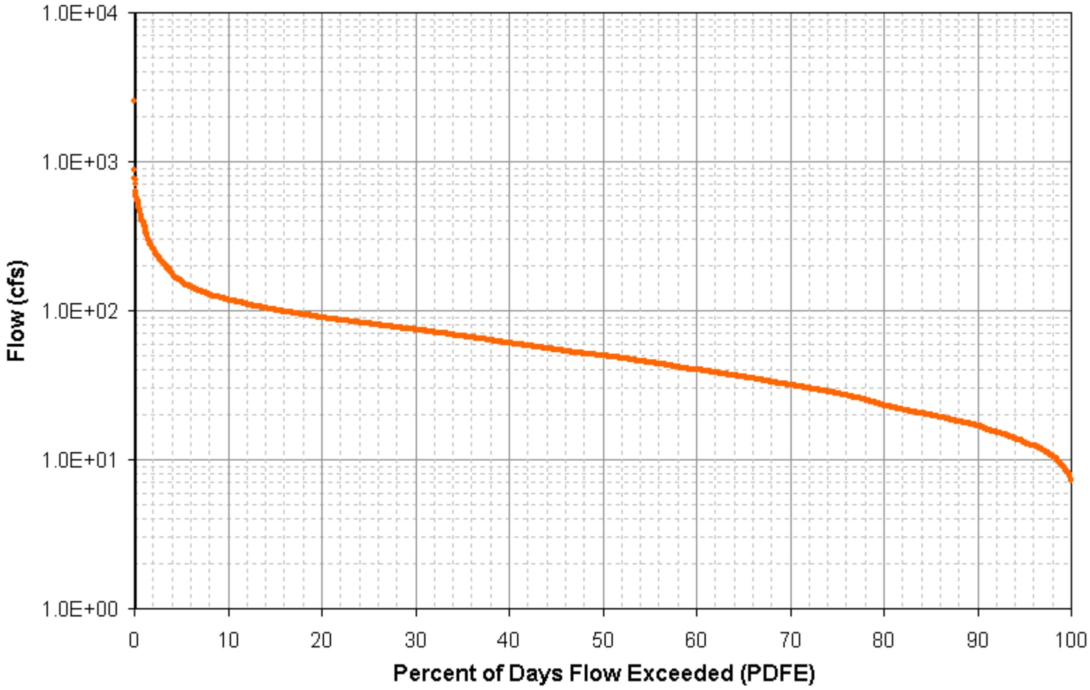

Figure C-1. Flow Duration Curve for Roan Creek at Mile 16.4

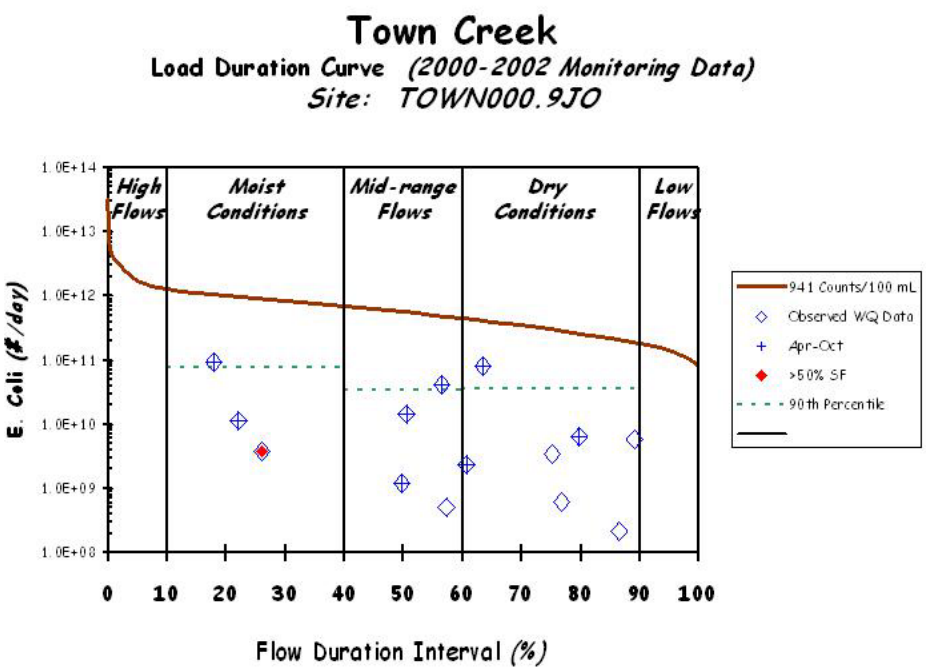

Figure C-2. E. Coli Load Duration Curve for Town Creek at Mile 0.9

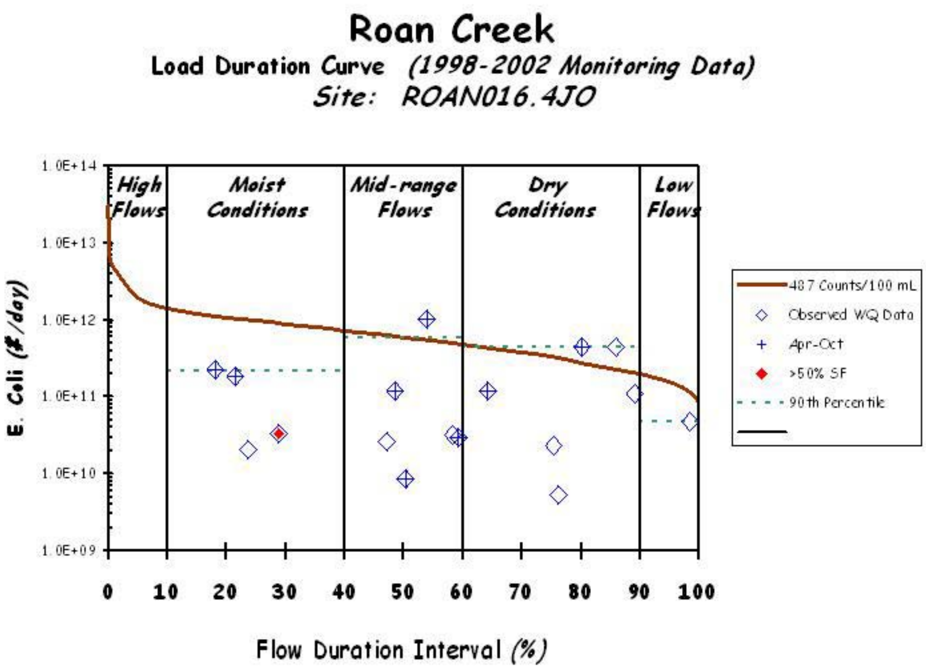

Figure C-3. E. Coli Load Duration Curve for Roan Creek at Mile 16.4

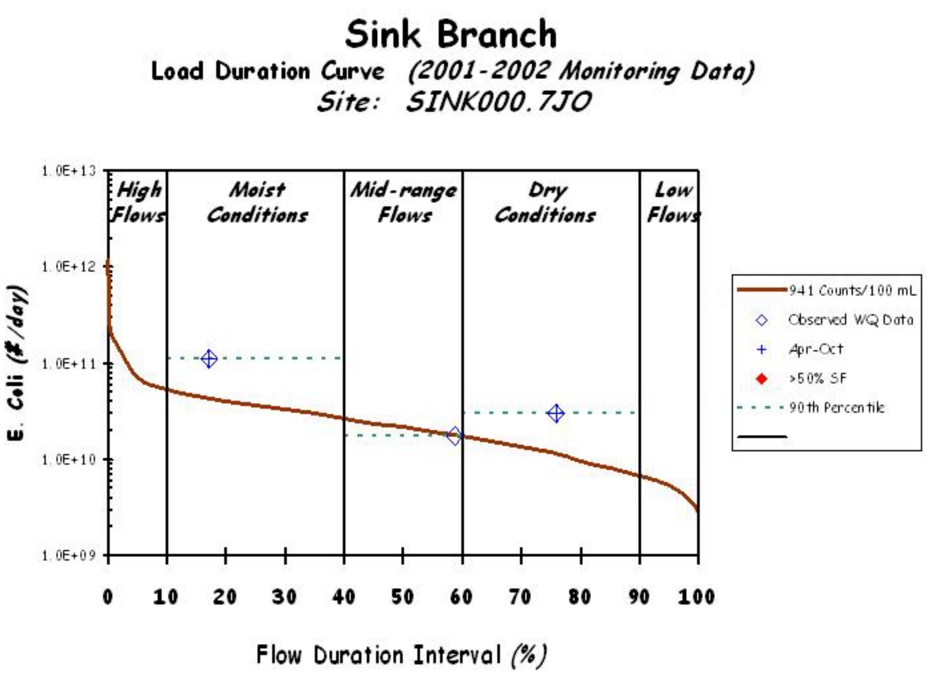

Figure C-4. E. Coli Load Duration Curve for Sink Branch at Mile 0.7

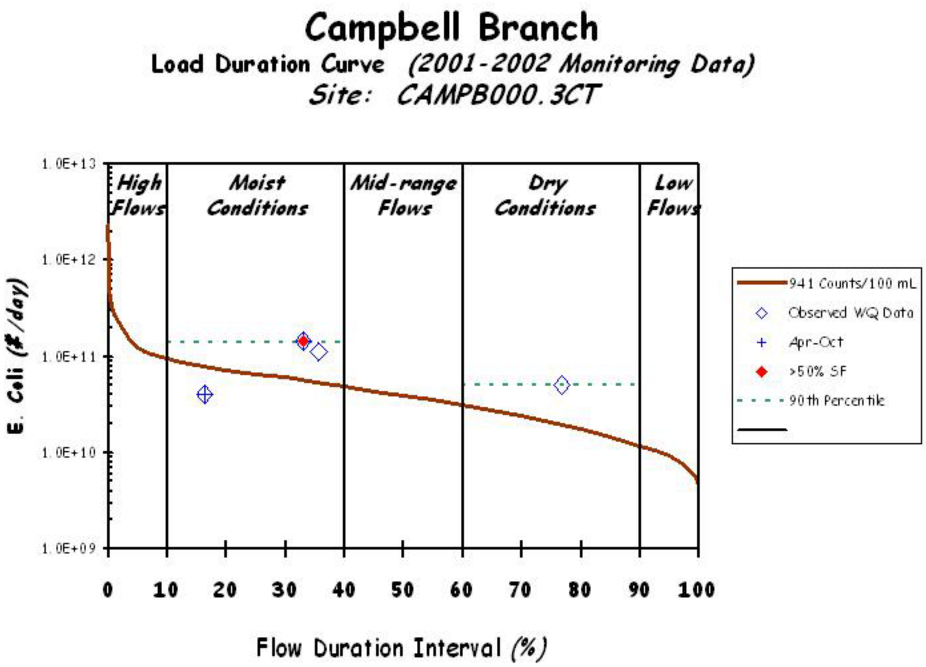

Figure C-5. E. Coli Load Duration Curve for Campbell Branch at Mile 0.3

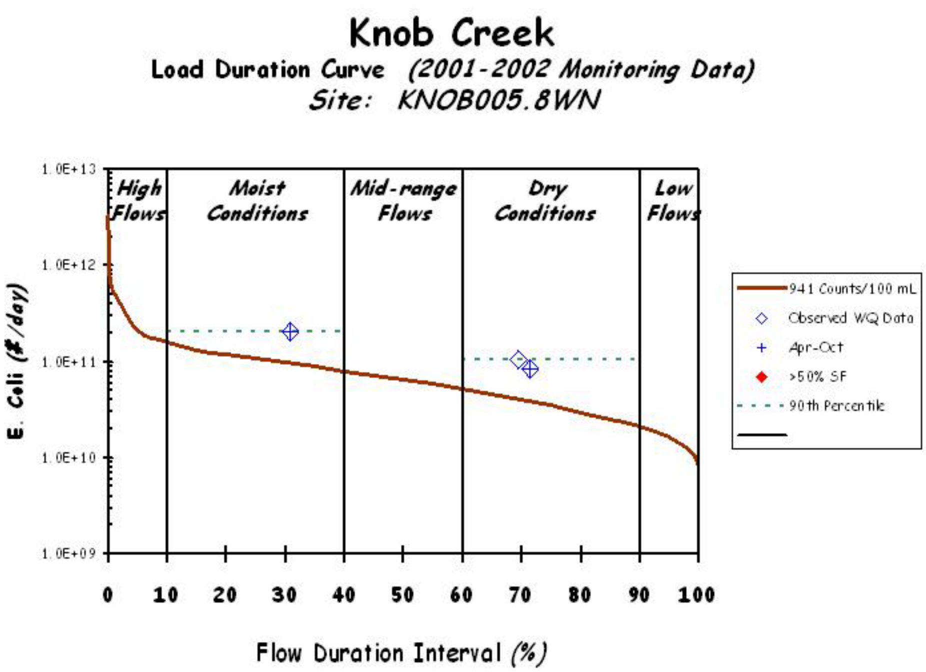

Figure C-6. E. Coli Load Duration Curve for Knob Creek at Mile 5.8

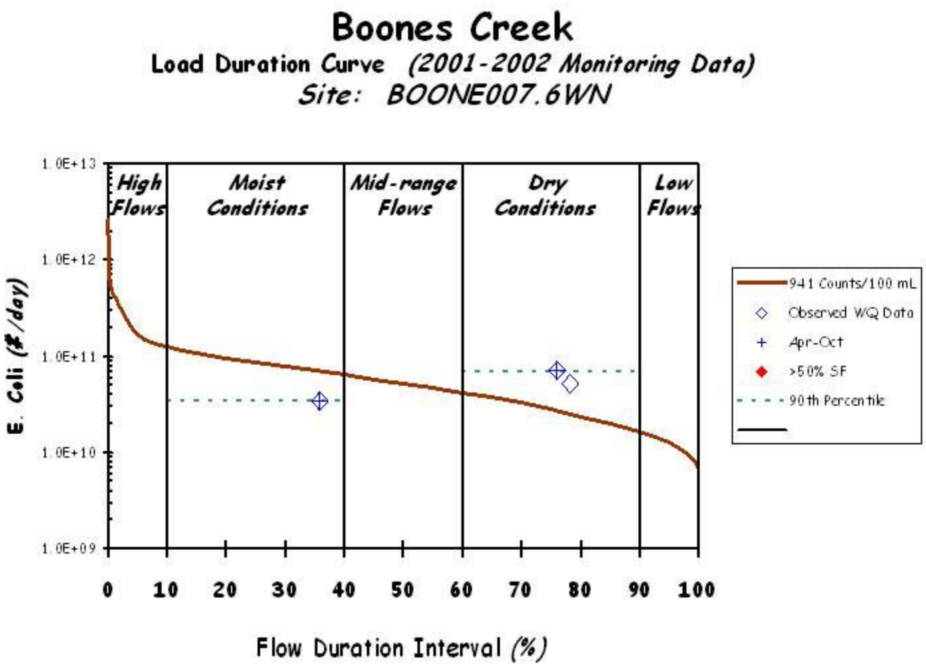

Figure C-7. E. Coli Load Duration Curve for Boones Creek at Mile 7.6

Table C-1. Required Load Reduction for Town Creek – Mile 0.9

Sample Date	Flow	PDFE	Sample Concentration	Required Reduction: Sample to Target (941 CFU/100 ml)	Required Reduction: Sample to Target – MOS (847 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[%]	[%]
11/15/00	8.05	89.3%	29	**NR**	**NR**
5/15/01	17.85	63.6%	186	**NR**	**NR**
7/18/01	21.04	56.5%	81	**NR**	**NR**
8/8/01	45.82	17.9%	84	**NR**	**NR**
9/5/01	41.90	22.2%	11	**NR**	**NR**
10/10/01	19.02	60.7%	5	**NR**	**NR**
11/7/01	12.47	76.8%	2	**NR**	**NR**
12/5/01	8.95	86.6%	1	**NR**	**NR**
1/16/02	12.99	75.3%	11	**NR**	**NR**
2/6/02	39.14	26.0%	4	**NR**	**NR**
3/13/02	20.53	57.4%	1	**NR**	**NR**
4/23/02	24.32	49.8%	2	**NR**	**NR**
5/8/02	23.94	50.5%	25	**NR**	**NR**
6/11/02	11.15	79.9%	24	**NR**	**NR**
90th Percentile Concentration			**83**	**NR**	**NR**

Note: NR = No reduction required
[a] Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.
[b] Reductions for individual samples (shaded area) are included for reference only.

Table C-2. Required Load Reduction for Roan Creek – Mile 16.4

Sample Date	Flow	PDFE	Sample Concentration	Required Reduction	
				Sample to Target (487 CFU/100 ml)	Sample to Target – MOS (438 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[%]	[%]
11/18/98	9.61	98.7%	205	**NR**	**NR**
2/9/99	52.04	47.3%	21	**NR**	**NR**
11/15/00	17.42	89.2%	260	**NR**	**NR**
2/27/01	83.42	23.8%	10	**NR**	**NR**
5/15/01	36.58	64.3%	135	**NR**	**NR**
7/18/01	45.93	53.9%	921	47.1	52.4
8/8/01	93.77	18.2%	99	**NR**	**NR**
9/5/01	87.23	21.5%	87	**NR**	**NR**
10/10/01	40.45	59.4%	30	**NR**	**NR**
11/7/01	26.85	76.2%	8	**NR**	**NR**
12/5/01	19.31	86.0%	921	47.1	52.4
1/16/02	27.47	75.5%	35	**NR**	**NR**
2/6/02	75.86	28.9%	18	**NR**	**NR**
3/13/02	41.42	58.3%	32	**NR**	**NR**
4/23/02	50.85	48.7%	94	**NR**	**NR**
5/8/02	49.52	50.4%	7	**NR**	**NR**
6/11/02	22.96	80.3%	792	38.5	44.7
90th Percentile Concentration			**844**	**42.3**	**48.1**

Note: NR = No reduction required
[a] Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.
[b] Reductions for individual samples (shaded area) are included for reference only.

Table C-3. Required Load Reduction for Campbell Creek – Mile 0.4

Sample Date	Flow	PDFE	Sample Concentration	Required Reduction	
				Sample to Target (487 CFU/100 ml)	Sample to Target – MOS (438 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[%]	[%]
7/10/01	4.10	34.4%	548	11.1	20.1
10/23/01	1.94	67.9%	162	**NR**	**NR**
1/9/02	1.85	69.7%	3	**NR**	**NR**
5/14/02	2.95	49.5%	12	**NR**	**NR**
90th Percentile Concentration			**432**	**NR**	**NR**

Note: NR = No reduction required
[a] Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.
[b] Reductions for individual samples (shaded area) are included for reference only.

Table C-4. Required Load Reduction for Sink Branch – Mile 0.7

Sample Date	Flow	PDFE	Sample Concentration	Required Reduction	
				Sample to Target (941 CFU/100 ml)	Sample to Target – MOS (847 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[%]	[%]
9/4/01	1.87	17.1%	>2419	>61.1	>65.0
3/12/02	0.77	58.8%	921	**NR**	8.0
6/5/02	0.50	75.8%	>2419	>61.1	>65.0
90th Percentile Concentration			**>2419**	**>61.1**	**>65.0**

Note: NR = No reduction required
[a] Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.
[b] Reductions for individual samples (shaded area) are included for reference only.

Table C-5. Required Load Reduction for Campbell Branch – Mile 0.3

Sample Date	Flow	PDFE	Sample Concentration	Required Reduction	
				Sample to Target (941 CFU/100 ml)	Sample to Target – MOS (847 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[%]	[%]
8/7/01	3.41	16.3%	488	**NR**	**NR**
11/6/01	0.86	76.9%	>2419	>61.1	>65.0
2/5/02	2.33	35.7%	1986	52.6	57.4
5/7/02	2.46	33.0%	>2419	>61.1	>65.0
90th Percentile Concentration			**>2419**	**>61.1**	**>65.0**

Note: NR = No reduction required
[a] Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.
[b] Reductions for individual samples (shaded area) are included for reference only.

Table C-6. Required Load Reduction for Sinking Creek – Mile 0.6

Sample Date	Flow	PDFE	Sample Concentration	Required Reduction		Geometric Mean[a]	Required Reduction	
				Sample to Target (487 CFU/100 ml)	Sample to Target – MOS (438 CFU/100 ml)		Sample to Target (126 CFU/100 ml)	Sample to Target – MOS (113 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[%]	[%]	[CFU/100 ml]	[%]	[%]
9/9/99	3.71	86.1%	579	15.9	24.4			
3/7/00	6.33	70.2%	130	**NR**	**NR**			
3/9/00	5.99	72.1%	80	**NR**	**NR**			
3/14/00	8.67	57.8%	192	**NR**	**NR**			
3/16/00	10.05	51.2%	102	**NR**	**NR**			
3/21/00	31.32	6.5%	210	**NR**	**NR**	133.73	5.8	15.5
3/23/00	16.66	25.9%	44	**NR**	**NR**	111.11		
3/28/00	12.99	38.6%	115	**NR**	**NR**	111.66		
3/30/00	17.57	23.2%	147	**NR**	**NR**	115.57		2.2
4/3/00	35.09	5.2%	1553	68.6	71.8	154.24	18.3	26.7
4/4/00	31.24	6.5%	>2419	>79.9	>81.9	203.12	**44.4**	**48.0**
90th Percentile Concentration			**>1553**	**>68.6**	**>71.8**			

Note: NR = No reduction required
[a] Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.
[b] Reductions for individual samples (shaded area) are included for reference only.

Table C-7. Required Load Reduction for Cash Hollow Creek – Mile 0.3

Sample Date	Flow	PDFE	Sample Concentration	Required Reduction: Sample to Target (941 CFU/100 ml)	Required Reduction: Sample to Target – MOS (847 CFU/100 ml)	Geometric Mean[a]	Required Reduction: Sample to Target (126 CFU/100 ml)	Required Reduction: Sample to Target – MOS (113 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[%]	[%]	[CFU/100 ml]	[%]	[%]
9/9/99	0.85	83.6%	159	**NR**	**NR**			
3/7/00	1.59	64.9%	185	**NR**	**NR**			
3/9/00	1.50	67.0%	162	**NR**	**NR**			
3/14/00	2.16	52.6%	222	**NR**	**NR**			
3/16/00	2.25	50.5%	>2419	>61.1	>65.0			
3/21/00	6.31	7.6%	579	**NR**	**NR**	392.53	**67.9**	**71.2**
3/23/00	4.15	21.0%	114	**NR**	**NR**	319.43	60.6	64.6
3/28/00	3.18	34.7%	114	**NR**	**NR**	275.71	54.3	59.0
3/29/00	3.05	36.9%	613	**NR**	**NR**	304.67	58.6	62.9
4/3/00	6.19	8.0%	1553	39.4	45.5	365.11	65.5	69.1
4/4/00	5.99	8.8%	687	**NR**	**NR**	388.93	67.6	70.9
90th Percentile Concentration			**>1553**	**>39.4**	**>45.5**			

Note: NR = No reduction required
[a] Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.
[b] Reductions for individual samples (shaded area) are included for reference only.

Table C-8. Required Load Reduction for Knob Creek – Mile 5.8

Sample Date	Flow	PDFE	Sample Concentration	Required Reduction	
				Sample to Target (941 CFU/100 ml)	Sample to Target – MOS (847 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[%]	[%]
8/21/01	4.18	30.8%	1986	52.6	57.4
11/14/01	1.79	69.6%	>2419	>61.1	>65.0
6/4/02	1.72	71.5%	1986	52.6	57.4
90th Percentile Concentration			**>2332**	**>59.6**	**>63.7**

Note: NR = No reduction required
[a] Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.
[b] Reductions for individual samples (shaded area) are included for reference only.

Table C-9. Required Load Reduction for Boones Creek – Mile 7.6

Sample Date	Flow	PDFE	Sample Concentration	Required Reduction	
				Sample to Target (941 CFU/100 ml)	Sample to Target – MOS (847 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[%]	[%]
8/21/01	3.05	35.9%	461	**NR**	**NR**
11/14/01	1.08	78.3%	1986	52.6	57.4
6/4/02	1.19	76.0%	>2419	>61.1	>65.0
90th Percentile Concentration			**>2332**	**>59.6**	**>63.7**

Note: NR = No reduction required
[a] Geometric Mean is calculated whenever 5 or more samples are collected over a period of not more than 30 consecutive days.
[b] Reductions for individual samples (shaded area) are included for reference only.

Table C-10 TMDLs, WLAs, & LAs for Watauga River Watershed

HUC-12 Subwatershed (06010103__) or Drainage Area	Impaired Waterbody Name	Impaired Waterbody ID	TMDL	WLAs				LAs	
				WWTFs [a,c]		CAFOs	MS4s [c]	Precipitation Induced Nonpoint Sources	Other Direct Sources [d]
				Monthly Avg.	Daily Max.				
			[% Red.]	[CFU/day]	[CFU/day]	[CFU/day]	[% Red.]	[% Red.]	[CFU/day]
0102	Town Creek	TN06010103034 – 0300	0	5.723×10^{9}	4.274×10^{10}	NA	NA	0	0
DA	Roan Creek	TN06010103034 – 2000	42.3	5.723×10^{9}	4.274×10^{10}	0	NA	48.1	0
DA	Campbell Creek	TN06010103037 – 0400	0	NA	NA	NA	NA	0	0
DA	Sink Branch	TN06010103020T – 0200	>61.1	NA	NA	NA	NA	>65.0	0
DA	Campbell Branch	TN06010103008 – 0200	>61.1	7.631×10^{7}	5.699×10^{8}	NA	>65.0	>65.0	0
0504	Sinking Creek	TN06010103046 – 1000	>68.6	NA	NA	NA	>71.8	>71.8	0
0505	Cash Hollow Creek	TN06010103035 – 0100	67.9	NA	NA	NA	71.2	71.2	0
	Knob Creek	TN06010103035 – 1000							
0508	Boones Creek	TN06010103006 – 1000	>59.6	NA	NA	NA	>63.7	>63.7	0

Notes: NA = Not Applicable.

a. Future WWTFs must meet instream water quality standards at the point of discharge as specified in their NPDES permit.
b. The WLAs listed apply to NPDES permitted discharges from WWTFs only. Pathogen loading due to collection system failure is considered to be unpermitted point source loading from the municipal WWTF. With respect to pathogen loading from leaking collection systems, a WLA of zero is assigned. It is recognized, however, that a WLA of 0 CFU/day may not be practical. For these unpermitted sources, the WLA is interpreted to mean a reduction in pathogen loading to the maximum extent practicable, consistent with the requirement that these sources not contribute to a violation of the water quality standard for E. coli.
c. Applies to any MS4 discharge loading in the subwatershed.
d. The objective for all “other direct sources” is a load allocation of zero. It is recognized, however, that for leaking septic systems a LA of 0 CFU/day may not be practical. For these sources, the LA is interpreted to mean a reduction in pathogen loading to the maximum extent practicable, consistent with the requirement that these sources not contribute to a violation of the water quality standard for E. coli.

APPENDIX D

Hydrodynamic Modeling Methodology

HYDRODYNAMIC MODELING METHODOLOGY

D.1 Model Selection

The Loading Simulation Program C++ (LSPC) was selected for flow simulation of pathogen-impaired waters in the subwatersheds of the Watauga Watershed. LSPC is a watershed model capable of performing flow routing through stream reaches. LSPC is a dynamic watershed model based on the Hydrologic Simulation Program - Fortran (HSPF)

D.2 Model Set Up

The Watauga Watershed was delineated into subwatersheds in order to facilitate model hydrologic calibration. Boundaries were constructed so that subwatershed “pour points” coincided with HUC-12 delineations, 303(d)-listed waterbodies, and water quality monitoring stations. Watershed delineation was based on the NHD stream coverage and Digital Elevation Model (DEM) data. This discretization facilitates simulation of daily flows at water quality monitoring stations.

Several computer-based tools were utilized to generate input data for the LSPC model. The Watershed Characterization System (WCS), a geographic information system (GIS) tool, was used to display, analyze, and compile available information to support hydrology model simulations for selected subwatersheds. This information includes land use categories, point source dischargers, soil types and characteristics, population data (human and livestock), and stream characteristics.

An important factor influencing model results is the precipitation data contained in the meteorological data files used in these simulations. Weather data from multiple meteorological stations were available for the time period from January 1970 through August 2004. Meteorological data for a selected 11-year period were used for all simulations. The first year of this period was used for model stabilization with simulation data from the subsequent 10-year period (10/1/94 – 9/30/04) used for TMDL analysis.

D.3 Model Calibration

Hydrologic calibration of the watershed model involves comparison of simulated streamflow to historic streamflow data from U. S. Geological Survey (USGS) stream gaging stations for the same period of time. A USGS continuous record station located near the Watauga Watershed with a sufficiently long and recent historical record was selected as the basis of the hydrology calibration. The USGS station was selected based on similarity of drainage area, Level IV ecoregion, land use, and topography. The calibration involved comparison of simulated and observed hydrographs until statistical stream volumes and flows were within acceptable ranges as reported in the literature (Lumb, et al., 1994).

Initial values for hydrologic variables were taken from an EPA developed default data set. During the calibration process, model parameters were adjusted within reasonable constraints until acceptable agreement was achieved between simulated and observed streamflow. Model parameters adjusted include: evapotranspiration, infiltration, upper and lower zone storage, groundwater storage, recession, losses to the deep groundwater system, and interflow discharge.

The results of the hydrologic calibration for Watauga River near Sugar Grove, North Carolina, USGS Station 03479000, are shown in Table D-1 and Figures D-1 and D-2.

Table D-1. Hydrologic Calibration Summary: Watauga River (USGS 03479000)

		90.03685086	
Simulation Name:	USGS034679000	**Simulation Period:**	
		Watershed Area (ac):	57642.03
Period for Flow Analysis			
Begin Date:	**10/01/90**	**Baseflow PERCENTILE:**	2.5
End Date:	**09/30/00**	*Usually 1%-5%*	
Total Simulated In-stream Flow:	**279.14**	Total Observed In-stream Flow:	**287.45**
Total of highest 10% flows:	**112.83**	Total of Observed highest 10% flows:	**119.65**
Total of lowest 50% flows:	**51.31**	Total of Observed Lowest 50% flows:	**52.05**
Simulated Summer Flow Volume (months 7-9):	**38.04**	Observed Summer Flow Volume (7-9):	**37.10**
Simulated Fall Flow Volume (months 10-12):	**57.06**	Observed Fall Flow Volume (10-12):	**54.65**
Simulated Winter Flow Volume (months 1-3):	**109.31**	Observed Winter Flow Volume (1-3):	**115.74**
Simulated Spring Flow Volume (months 4-6):	**74.73**	Observed Spring Flow Volume (4-6):	**79.96**
Total Simulated Storm Volume:	**240.50**	Total Observed Storm Volume:	**245.38**
Simulated Summer Storm Volume (7-9):	**28.28**	Observed Summer Storm Volume (7-9):	**26.59**
Errors (Simulated-Observed)		*Recommended Criteria*	Last run
Error in total volume:	**-2.89**	10	
Error in 50% lowest flows:	**-1.43**	10	
Error in 10% highest flows:	**-5.70**	15	
Seasonal volume error - Summer:	**2.54**	30	
Seasonal volume error - Fall:	**4.40**	30	
Seasonal volume error - Winter:	**-5.56**	30	
Seasonal volume error - Spring:	**-6.53**	30	
Error in storm volumes:	**-1.99**	20	
Error in summer storm volumes:	**6.38**	50	

Criteria for Median Monthly Flow Comparisons	
Lower Bound (Percentile):	25
Upper Bound (Percentile):	75

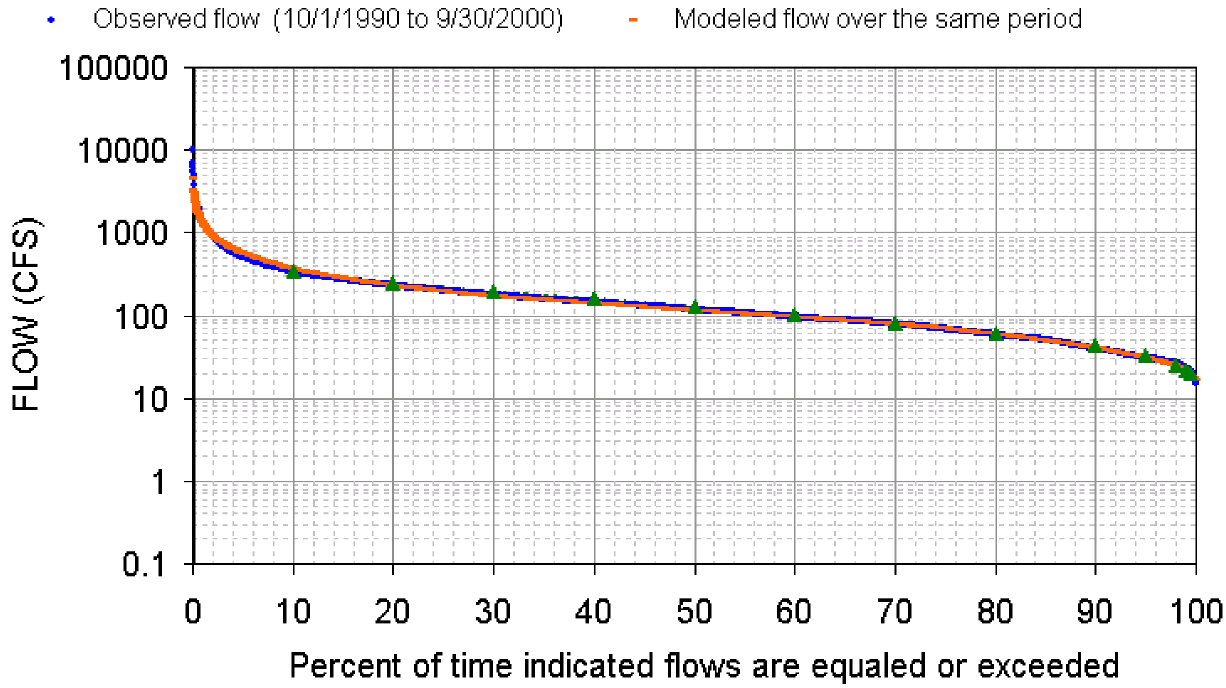

Figure D-1. Hydrologic Calibration: Watauga River, USGS 03479000 (WYs1991-2000)

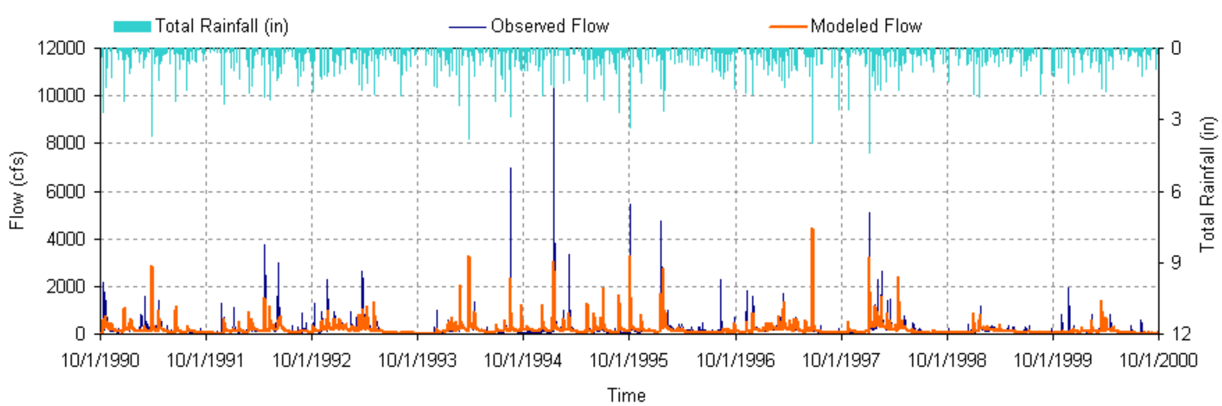

Figure D-2. 10-Year Hydrologic Comparison: Watauga River, USGS 03479000

APPENDIX E

De-Listing Analysis for Town Creek

Analysis of E. coli monitoring data for Town Creek is included in Appendix C (see Figure C-2 and Table C-1).

Sufficient fecal coliform monitoring data was available for Town Creek to allow comparison of two different time periods. Monitoring data for 1996 – 2000 is presented in Table E-1. Monitoring data for 2001 – 2002 is presented in Table E-2. Examination of this data suggests that improvement in water quality has occurred since the previous TMDL was approved in 2001. The Fecal Load Duration Curve for Town Creek illustrates the decrease in the 90th percentile in both the moist and dry flow regimes (see Figure E-1). The Fecal Coliform Monitoring Data Trend Analysis shows lower values for most months, with a slight overlap in September and November due to multiple data points (see Figure E-2).

At this time, delisting is recommended for Town Creek.

Table E-1. Required Load Reduction for Town Creek – Mile 0.9 – Monitoring Data for 1996 – 2000

Sample Date	Flow	PDFE	Fecal Coliform Sample Concentration	Required Reduction	
				Sample to Target (1000 CFU/100 ml)	Sample to Target – MOS (900 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[%]	[%]
8/6/96	16.89	65.7%	710	**NR**	**NR**
10/22/96	10.37	82.0%	1,330	24.8	32.3
2/4/97	48.81	15.3%	1,700	41.2	47.1
5/14/97	31.52	37.5%	200	**NR**	**NR**
8/19/97	14.12	72.7%	260	**NR**	**NR**
11/18/97	7.65	90.7%	10	**NR**	**NR**
2/26/98	25.46	47.4%	80	**NR**	**NR**
5/19/98	39.57	25.5%	164	**NR**	**NR**
8/4/98	16.97	65.6%	170	**NR**	**NR**
11/18/98	4.55	98.7%	10	**NR**	**NR**
2/9/99	27.35	44.0%	68	**NR**	**NR**
5/13/99	25.08	48.2%	320	**NR**	**NR**
8/17/99	14.63	71.4%	102	**NR**	**NR**
11/2/99	12.85	75.8%	550	**NR**	**NR**
2/9/00	18.85	61.2%	250	**NR**	**NR**
8/3/00	18.25	62.7%	2,000	50.0	55.0
11/15/00	8.05	89.3%	20	**NR**	**NR**
90th Percentile Concentration			**1,478**	**32.3**	**39.1**

Note: NR = No reduction required
b Reductions for individual samples (shaded area) are included for reference only.

Table E-2. Required Load Reduction for Town Creek – Mile 0.9 – Monitoring Data for 2001 – 2002

Sample Date	Flow	PDFE	Fecal Coliform Sample Concentration	Required Reduction	
				Sample to Target (1000 CFU/100 ml)	Sample to Target – MOS (900 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[%]	[%]
5/15/01	17.85	63.6%	152	**NR**	**NR**
7/18/01	21.04	56.5%	186	**NR**	**NR**
8/8/01	45.82	17.9%	168	**NR**	**NR**
9/5/01	41.90	22.2%	290	**NR**	**NR**
10/10/01	19.02	60.7%	24	**NR**	**NR**
11/7/01	12.47	76.8%	16	**NR**	**NR**
12/5/01	8.95	86.6%	14	**NR**	**NR**
1/16/02	12.99	75.3%	16	**NR**	**NR**
2/6/02	39.14	26.0%	46	**NR**	**NR**
4/23/02	24.32	49.8%	18	**NR**	**NR**
5/8/02	23.94	50.5%	340	**NR**	**NR**
6/11/02	11.15	79.9%	172	**NR**	**NR**
90th Percentile Concentration			**280**	**NR**	**NR**

Note: NR = No reduction required
[b] Reductions for individual samples (shaded area) are included for reference only.

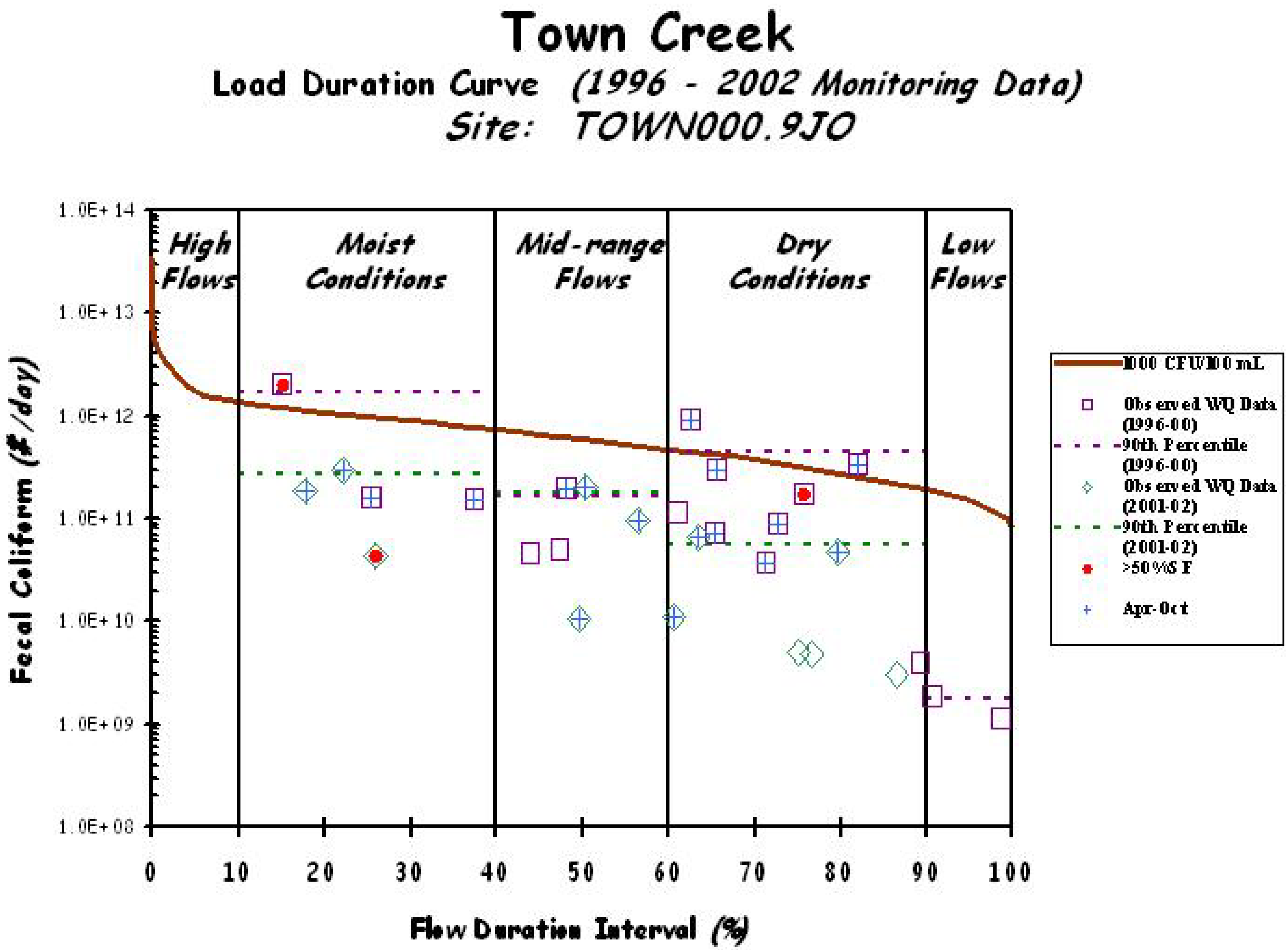

Figure E-1. Fecal Coliform Load Duration Curve for Town Creek at Mile 0.9

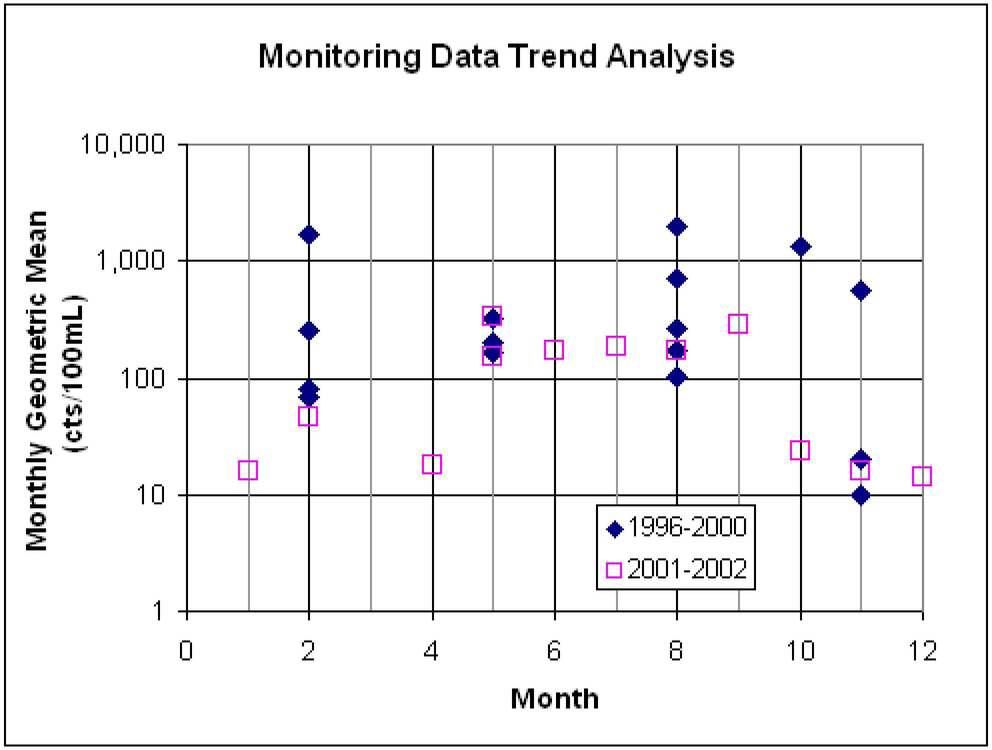

Figure E-2. Fecal Coliform Monitoring Data Trend Analysis for Town Creek at Mile 0.9

APPENDIX F

Public Notice Announcement

STATE OF TENNESSEE
DEPARTMENT OF ENVIRONMENT AND CONSERVATION
DIVISION OF WATER POLLUTION CONTROL

PUBLIC NOTICE OF AVAILABILITY OF PROPOSED TOTAL MAXIMUM DAILY LOAD (TMDL) FOR E. COLI IN WATAUGA WATERSHED (HUC 06010103), TENNESSEE

Announcement is hereby given of the availability of Tennessee's proposed Total Maximum Daily Load (TMDL) for E. coli in the Watauga watershed, located in eastern Tennessee. Section 303(d) of the Clean Water Act requires states to develop TMDLs for waters on their impaired waters list. TMDLs must determine the allowable pollutant load that the water can assimilate, allocate that load among the various point and nonpoint sources, include a margin of safety, and address seasonality.

A number of waterbodies in the Watauga River watershed are listed on Tennessee's Final 2004 303(d) list as not supporting designated use classifications due, in part, to discharge of pathogens from pasture land and livestock in stream. The TMDL utilizes Tennessee's general water quality criteria, continuous flow data from a USGS discharge monitoring station located in proximity to the watershed, site specific water quality monitoring data, a calibrated hydrologic model, load duration curves, and an appropriate Margin of Safety (MOS) to establish allowable loadings of pathogens which will result in the reduced in-stream concentrations and attainment of water quality standards. The TMDL requires reductions of pathogen loading on the order of 42-68% in the listed waterbodies.

The proposed Watauga E. coli TMDL may be downloaded from the Department of Environment and Conservation website:

http://www.state.tn.us/environment/wpc/tmdl/

Technical questions regarding this TMDL should be directed to the following members of the Division of Water Pollution Control staff:

Vicki S. Steed, P.E., Watershed Management Section
Telephone: 615-532-0707

Sherry H. Wang, Ph.D., Watershed Management Section
Telephone: 615-532-0656

Persons wishing to comment on the proposed TMDLs are invited to submit their comments in writing no later than March 27, 2006 to:

Division of Water Pollution Control
Watershed Management Section
7th Floor, L & C Annex
401 Church Street
Nashville, TN 37243-1534

All comments received prior to that date will be considered when revising the TMDL for final submittal to the U.S. Environmental Protection Agency.

The TMDL and supporting information are on file at the Division of Water Pollution Control, 6th Floor, L & C Annex, 401 Church Street, Nashville, Tennessee. They may be inspected during normal office hours. Copies of the information on file are available on request.